NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

EVOLUTION OF THE OPERATIONAL ENERGY STRATEGY AND ITS CONSIDERATION IN THE DEFENSE ACQUISITION PROCESS

by

Richard J. Kendig
Ashley D. Seaton
Robert J. Rodgers

September 2016

Thesis Advisor: Michael Boudreau
Co-Advisor: Robert Sheibley

Approved for public release. Distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** September 2016	**3. REPORT TYPE AND DATES COVERED** Joint applied project	
4. TITLE AND SUBTITLE EVOLUTION OF THE OPERATIONAL ENERGY STRATEGY AND ITS CONSIDERATION IN THE DEFENSE ACQUISITION PROCESS			**5. FUNDING NUMBERS**
6. AUTHOR(S) Richard J. Kendig, Ashley D. Seaton, and Robert J. Rodgers			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			**12b. DISTRIBUTION CODE**
13. ABSTRACT (maximum 200 words) Our team looked at the DOD Operational Energy Strategy evolution and how it applies to new and modified weapon systems, considering the three-legged table of the acquisition system: 1) acquisition, 2) requirements and 3) planning, programming, budgeting, and execution (PPBE). We looked at the evolution of the operational energy area initiatives (executive orders, Defense Science Board studies, strategy and policy documents) with a focus on practical ways to gain traction or improve promulgation of key guidance and documentation for new-starts and/or upgrades to weapon system acquisition programs. Additionally, we highlight a few of the in-service initiatives and process improvements underway to reduce fuel consumption.			
14. SUBJECT TERMS operational energy, DOD acquisition system			**15. NUMBER OF PAGES** 93
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release. Distribution is unlimited.

EVOLUTION OF THE OPERATIONAL ENERGY STRATEGY AND ITS CONSIDERATION IN THE DEFENSE ACQUISITION PROCESS

Richard J. Kendig, Civilian, Department of the Army
Ashley D. Seaton, Civilian, Department of the Army
Robert J. Rodgers, Civilian, Department of the Army

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN PROGRAM MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
September 2016

Approved by: Michael Boudreau
Thesis Advisor

Robert Sheibley
Co-Advisor

Brad Naegle
Academic Associate
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Our team looked at the DOD Operational Energy Strategy evolution and how it applies to new and modified weapon systems, considering the three-legged table of the acquisition system: 1) acquisition, 2) requirements and 3) planning, programming, budgeting, and execution (PPBE). We looked at the evolution of the operational energy area initiatives (executive orders, Defense Science Board studies, strategy and policy documents) with a focus on practical ways to gain traction or improve promulgation of key guidance and documentation for new-starts and/or upgrades to weapon system acquisition programs. Additionally, we highlight a few of the in-service initiatives and process improvements underway to reduce fuel consumption.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

A2/AD	Anti-Access and Area Denial
ADRP	Army Doctrine Reference Publication
AOA	Analysis of Alternatives
AMC	Air Mobility Command
AO	Area of Operation
AOR	Area of Responsibility
AROC	Army Requirements Oversight Council
ASD(EI&E)	Assistant Secretary of Defense for Energy, Installations, and Environment
ASD(OEPP)	Assistant Secretary of Defense for Operational Energy Plans and Programs
CAPE	Cost Assessment and Program Evaluation
CDD	Capability Development Document
CJCS	Chairman of the Joint Chiefs of Staff
CONOPS	Concept of Operations
DAG	Defense Acquisition Guidebook
DCAPE	Director for Cost Assessment and Program Evaluation
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DLA	Defense Logistics Agency
DOEB	Defense Operational Energy Board
DON	Department of the Navy
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities
DPA&E	Director, Program Analysis and Evaluation
DSB	Defense Science Board
E-KPP	Energy Key Performance Parameter
ECP	Engineering Change Proposal
ESA	Energy Supportability Analyses

ET&E	Energy Training and Education
FBCE	Fully Burdened Cost of Energy
FBCF	Fully Burdened Cost of Fuel
FEMP	Federal Energy Management Program
FEO	Fuel Efficiency Office
FY	Fiscal Year
GAO	Government Accountability Office
HED	Hybrid Electric Drive
i-ENCON	Incentivized Energy Conservation Program
ITE	Improved Turbine Engine
ITEP	Improved Turbine Engine Program
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Council
JS/J4	Joint Staff/Director for Logistics
KPP	Key Performance Parameter
KSA	Key System Attribute
LOC	Line of Communication
MAF	Mobility Air Forces
MOS	Military Occupational Specialty
MS	Milestone
NMS	National Military Strategy
NSS	National Security Strategy
O&S	Operating and Support
OE	Operational Energy
OES	Operational Energy Strategy
OPTEMPO	Operational Tempo
PPBE	Planning, Programming, Budgeting, and Execution
PEO	Program Executive Officer
PM	Program Manager
QDR	Quadrennial Defense Review
SHP	Shaft Horsepower
TFMD	Tactical Fuels Manager Defense

TMRR	Technology Maturation and Risk Review
TOC	Total Ownership Cost
USC	United States Code
USCENTCOM	United States Central Command
USMC	United States Marine Corps
USPACOM	United States Pacific Command
USTRANSCOM	United States Transportation Command
WSARA	Weapon Systems Acquisition Reform Act

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

The authors of this research project explored the issues and concepts related to operational energy consumption, captured the essential Department of Defense operational energy guidance applicable to acquisition efforts, and identified how this guidance translates into the improved usage of operational energy (OE). Specifically, our team:

- Underscored the issues, costs, risks, and sustainment burden on deployed forces associated with heavy reliance upon significant quantities of operational energy, specifically fossil fuels
- Identified where operational energy policy is being incorporated into the requirements and acquisition processes, and determined the effectiveness of these decisions to reduce life-cycle energy consumption
- Examined emerging efforts to improve operational energy usage in existing DOD aircraft through the acquisition of “drop-in” replacement fuel-efficient turbine engines
- Assessed operational benefits and impacts of energy-related solutions that would be of interest to aviation concept developers and DOD acquisition communities

The authors intended to conduct a comprehensive review of operational energy policy and guidance in an effort to determine how operational energy efficiency concerns affects the acquisition process, with a focus on weapon systems consuming the most fuel—aviation platforms. Then we evaluated the extent to which efficiency targets are being met, and identified the factors that hinder or facilitate the realization of DOD and service efficiency goals.

The authors reviewed an Army weapon system program, the Improved Turbine Engine Program, in an effort to identify and report on the progress that is being made to develop more efficient propulsion systems. This included an in-depth examination of how operational energy guidance is shaping efforts to acquire a more powerful and fuel efficient turbine engine component for the AH-64 Apache and UH-60 Black Hawk helicopters, and how this forward thinking

can be applied throughout DOD. Additionally, the authors studied how the Improved Turbine Engine Program is considering energy efficiency parameters as a formal part of its acquisition process and how these lessons learned can assist other weapons systems programs.

I. INTRODUCTION

Multiple efforts are ongoing to make the Department of Defense (DOD) more energy efficient. Initiatives that are focused on reducing energy costs associated with DOD's fixed installations, albeit important, cannot have near the impact as improving the energy performance of major weapons systems would. Today, a gallon of gas costs the average American less than two dollars a gallon. Yet consider how much that same gallon costs (transportation and lives) when you have to transport it to the battle field front line in Afghanistan. Weapon system energy performance is categorized and defined under the term "operational energy," or OE. The reality is that operational energy accounts for the majority of DOD's energy consumption and therefore represents the area of greatest potential savings.

A. NEED FOR AN OE STRATEGY

Operational energy is, in every practical sense, the fuel utilized by our aircraft, ground vehicles, and ships. The availability of this fuel affects hours flown, miles driven, days at sea, supply chain vulnerabilities, and overall readiness. Despite advances in alternative fuels, DOD will be dependent upon fossil fuels well into the future. The budget environment, high OPTEMPO, threat conditions, inefficient platforms, and shrinking natural resources all contribute to this multifaceted problem of high dependence upon fossil fuels by our military forces.

Although operational performance considerations will always supplant energy efficiency in major weapons systems, gone are the days when the far-reaching effects of high levels of fossil fuel consumption can be ignored by DOD requirements and acquisition communities. Weapon systems cannot simply be fielded with the responsibility falling to the warfighter to employ operational techniques to manage fuel consumption. Weapon systems efficiency must be "designed in" as part of both the requirements and the development process.

Turbine engines, which provide the means of energy and propulsion for many of DOD's platforms (tanks, ships, and aircraft), must be considered as a prime candidate for fuel efficiency improvements. It is likely that relatively small investments in turbine engine technology can yield huge reductions in operational energy consumption and costs, while improving operational effectiveness and mission endurance.

B. RESOURCES

Multiple resources have been identified as to support the analysis, including several documents providing DOD's guidance on operational energy, including the DOD Operational Energy Strategy and the DOD Operational Energy Strategy Implementation Plan. Other documentation will be obtained from the Army's Improved Turbine Engine Program (ITEP). The ITEP Analysis of Alternatives captures a program-specific approach for finding alternative ways to improve energy efficiency. Documentation and reports from the U.S. Army Program Executive Officer-Aviation, particularly the project manager for Apache and the project manager for the Improved Turbine Engine Program, will be essential to understanding specific weapons systems acquisition efforts underway to improve utilization of fossil fuels.

C. DELIVERABLES

The joint applied project team will refer back to the project objectives, summarizing the methods used to examine them and identify the main conclusions and recommendations that can be drawn from this study. The deliverables will include:

- Conclusions as to the effectiveness of DOD's operational energy guidance based upon the best practices and lessons learned from current weapons systems meeting these initiatives
- Documentation of example(s) where investments in research, development, and testing result in efficiency improvements applicable to weapons platforms and the feasibility of applying

these energy efficiency upgrades to modernization efforts of legacy programs

- Recommendations for energy-related solutions and acquisition approaches that would be of benefit to aviation concept developers and acquisition communities

- Identification of areas where further work is needed to incorporate energy performance criteria and the implications for DOD

THIS PAGE INTENTIONALLY LEFT BLANK

II. RELEVANCE OF THE OE STRATEGY

The ability for the U.S. military to project power depends in many ways on the use of operational energy in the form of petroleum-based fuel products. Operational energy is still a relatively new area of interest for DOD, with the majority of the significant studies, plans, strategies and policies having been developed only within the last decade. The implementation of the overarching DOD Operational Energy Strategy should result in reduced costs, improvements in operational performance, and less risk for the warfighter.

A. ENERGY IS THE CRITICAL ENABLER

The mission statement of the Department of Defense is to "provide the military forces needed to deter war and to protect the security of our country" (DOD, n.d.). To accomplish its mission, DOD's corresponding National Military Strategy (NMS) consists of the following three foundational pillars: defense of the homeland, building security capacity globally, and the ability to project decisive combat power in support of national objectives. Successful implementation of the NMS depends, in large measure, on U.S. forces' ability to globally engage and forward deploy. Projecting sea, air, and land power worldwide requires access to the energy necessary to sustain DOD's weapons systems and mobility platforms. The availability of energy for military operations must serve as an advantage for U.S. forces, and not as a detriment. DOD's energy resources must be secure, of sufficient quantity, and available when needed for whatever duration is necessary to support the full spectrum of military missions. This makes energy the critical enabler that underpins our military's fundamental contribution to U.S. national security. Accordingly, it is essential that operational energy considerations be addressed in DOD's policies and factored into its weapons systems requirements and acquisition decisions.

B. OPERATIONAL ENERGY VERSUS FACILITY ENERGY

DOD's energy portfolio, for the purposes of management and formulating policy, classifies energy into two distinct categories: Facility energy (also referred to occasionally as installation energy) and operational energy. Facility energy is the energy required to heat, cool, and power buildings at DOD's fixed installations as well as the energy consumed by its non-tactical vehicle fleet. During FY2014, facility energy accounted for approximately 23% of DOD's total energy cost and 30% of total energy consumption (OASD(EI&E), 2015, p. 15). Efforts to manage facility energy consumption are accomplished through energy conservation measures in combination with renewable energy technologies. Facility energy, while relevant for comparison to operational energy within the context of DOD's total energy portfolio, is outside the scope of this study.

Operational energy, in contrast to facility energy, is defined by statute. Title 10 U.S. Code legally defines operational energy as "energy required for training, moving, and sustaining military forces and weapons platforms for military operations" (10 U.S. Code § 2924(5)). Similar to Congress' definition of operational energy, the Government Accountability Office (GAO) uses the terminology "mobility energy" as "the energy required for moving and sustaining DOD's forces and weapons platforms for military operations" (GAO, 2008, p. 1). The definition of operational energy can represent energy used by soldiers, weapons and mobility platforms, and contingency bases. Operational energy, as defined, can apply to different types of energy sources such as batteries used by soldiers to power their equipment. Practically speaking, operational energy is predominantly the liquid fuel utilized by our aircraft, ground vehicles, ships, and contingency bases. Despite technological advancements in alternative fuel options, petroleum-based fuels such as aviation fuel (and to a lesser extent diesel) remain the lifeblood of DOD weapons systems.

Figure 1 shows that aviation grade fuels comprise the largest portion of DOD's total operational energy consumption in FY2014, representing the area with the greatest potential to save the most number of gallons. Figure 1 also

illustrates that airborne tankers accounted for 12% of total operational energy use. This represents a significant amount of DOD's total operational energy being used for the purpose of transporting operational energy for other weapons systems. The availability of and access to operational energy directly affects hours flown, miles driven, days at sea, readiness and operations. During FY2014, operational energy accounted for approximately 77% of DOD's total energy cost and 70% of total energy consumption (OASD(EI&E), 2015, p. 15).

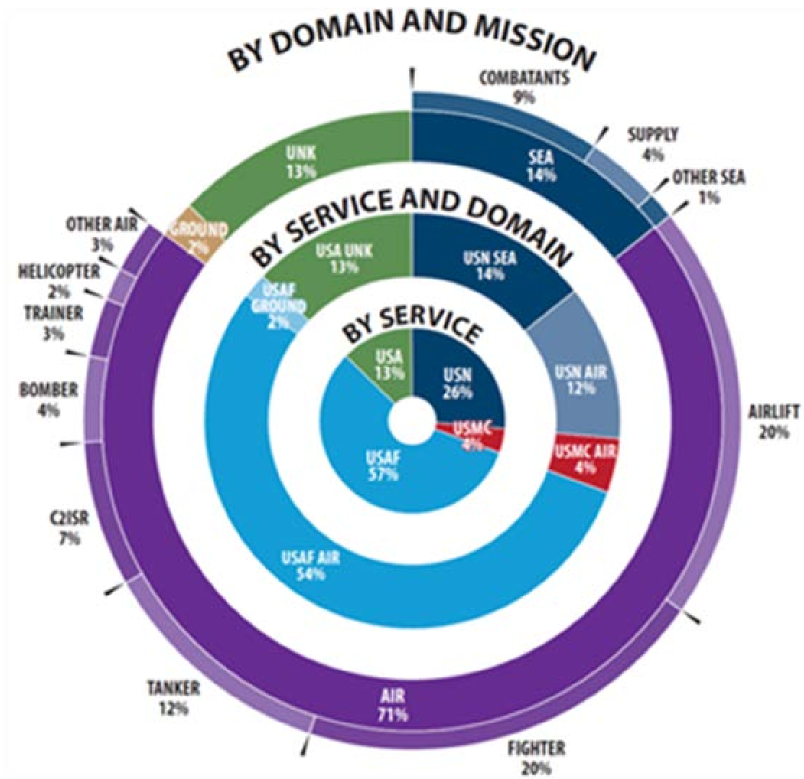


Figure 1. FY2014 Operational Energy Breakdown.
Source: DOD (2016), p. 4.

Figure 2 illustrates that operational energy comprises the majority share of DOD's energy cost and consumption, therefore offering the greatest area for potential savings. Operational energy management is not just about saving money, going "green" or the conservation of natural resources. The central focus

of operational energy management is about understanding and improving energy's contribution to overall operational efficiency and effectiveness.

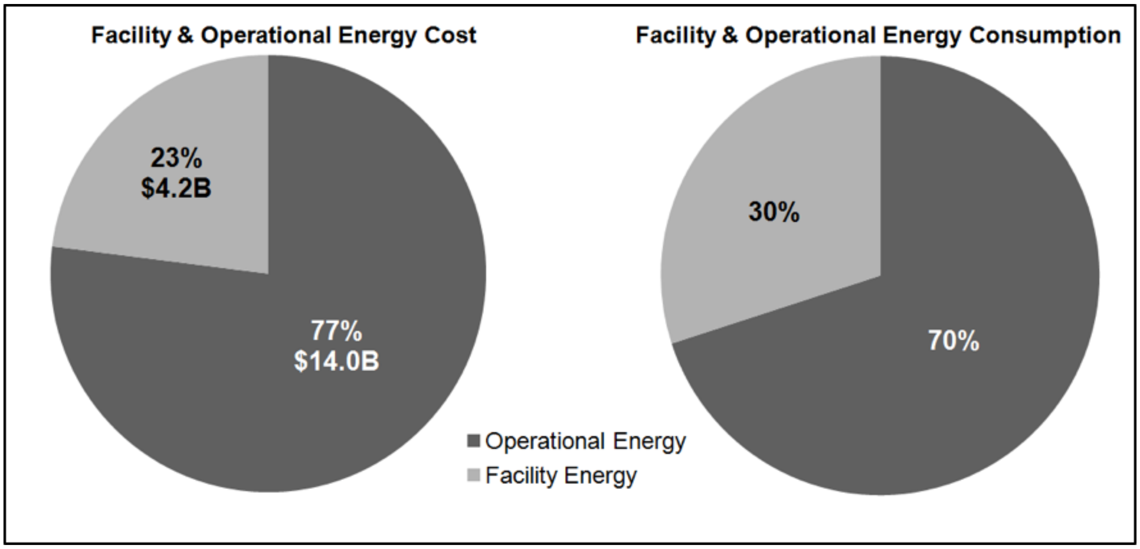


Figure 2. Facility and Operational Energy

Operational effectiveness benefits (such as extended range, endurance, and payload) that result from the increased energy performance of weapons systems are far more valuable to DOD than just saving fuel, but it must be noted that efficiency contributes to effectiveness. To achieve the goals of DOD's Operational Energy Strategy, the requirements and acquisition processes must work together to field weapons systems that have better energy performance while retaining or improving upon existing capabilities. It is arguable that facility energy initiatives, while important in their own right, do not offer the same potential return on investment for DOD's energy portfolio as improving the energy performance of weapons systems and mobility platforms.

Historical data for operational energy demand is based upon net sales of liquid fuels by the Defense Logistics Agency to the DOD Service Components. Per data obtained from the FY2014 Operational Energy Annual Report shown in Figure 3, operational energy demand per fiscal year went from 110.6 million barrels in FY2009 to 87.4 million in FY2014. This 23.2 million barrel reduction per

year in demand represents an almost 21% decrease per year in operational energy demand over the six year period. This reduction in demand is due in part to DOD's operational energy initiatives as well as the corresponding reduction in deployed forces in the USCENTCOM area of responsibility during the period of FY2011–FY2014. Requirements for operational energy per fiscal year are projected to remain flat over the period FY2014–FY2016. Expenditures per fiscal year for operational energy increased from FY2009 to FY2014 from $10.2 billion to $14.0 billion, respectively, a 37.25% increase over the six-year period, which is indicative of the long-term trend of rising oil prices. Expenditures for operational energy per fiscal year are anticipated to decline over the period FY2014–FY2016 by almost 8% (OUSD[AT&L], 2015, pp. 13–14).

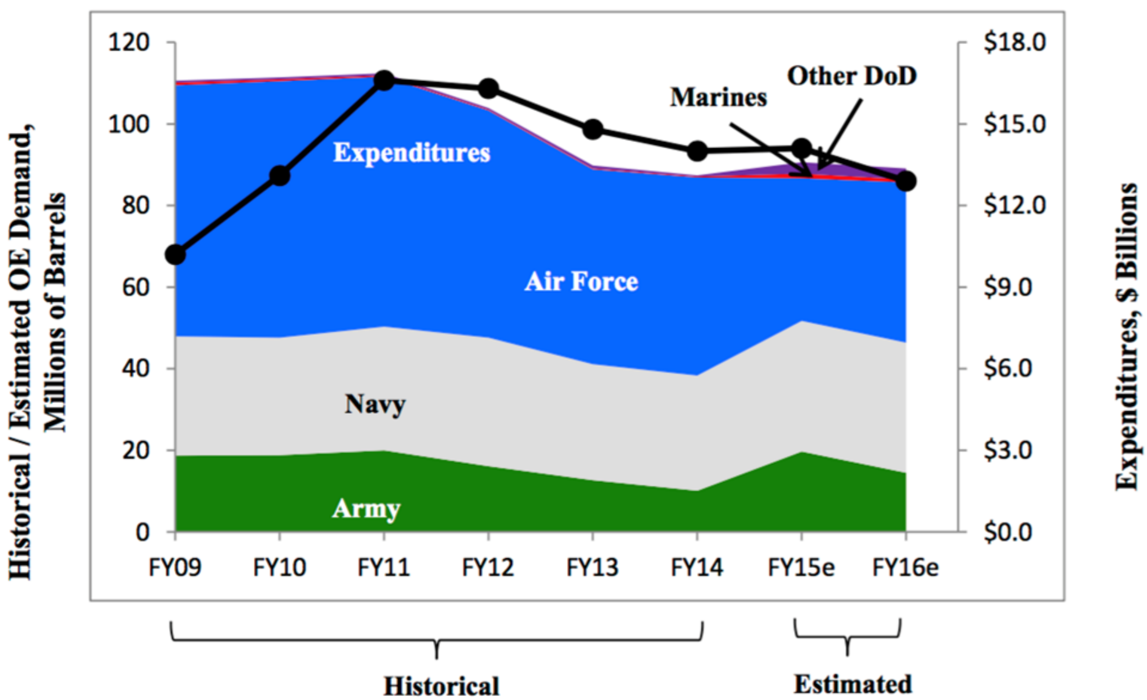


Figure 3. DOD Operational Energy Demand FY 2009–2016. Source: OUSD(AT&L) (2015), p. 13.

While the overall demand for operational energy has shown signs of decrease, the total operational energy demand remains high. DOD has made

military energy security a high priority to deal with threats to its energy supply and manage the challenges associated with demand for this mission critical resource. The concept of military energy security is described by the 2010 Quadrennial Defense Review (QDR) as “the assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet operational needs” (DOD, 2010, p. 87). Military energy security serves as a necessary precondition to the conduct of military operations because insufficient or interrupted energy supplies diminish operational capability and jeopardize mission success. There are significant financial, operational, and strategic challenges and risks to ensuring military energy security and they are all related to the dependence on petroleum-based fuels and the demand for this form of operational energy.

C. FINANCIAL CHALLENGES AND RISKS

DOD’s aggregate consumption of petroleum-based fuel and the financial cost with that consumption is staggering. The demand for operational energy over the period from FY2007 through FY2014 necessitated the purchase of 32 billion gallons of petroleum-based fuel at a cost of approximately $107.2 billion (GAO, 2015, p. 12). This level of military energy consumption makes the DOD our nation’s single largest energy consumer (EESI, 2011) and arguably the largest fuel consuming entity in the world. Ideologically motivated movements, violent extremist organizations, and geopolitical events all have the potential to negatively affect the price or availability of oil. The 1973 Yom Kippur War triggered in the 1973 oil crises, and the Iranian Revolution resulted in the 1979 oil crisis. Volatility in oil markets and rising energy costs creates uncertainty in the defense budget. DOD is not immune from the adverse effects of unstable supplies and rising energy costs. When the cost of fuel rises, this has an undesirable effect on DOD’s overall operating budget and undermines the U.S. military’s operational readiness. To put this in context, a $10 increase in a barrel of oil is estimated to increase the cost of DOD’s operations by $1.3 billion (Warner and Singer, 2008, p. 3). There’s also the

indirect cost associated with the U.S. military's enduring presence in the Persian Gulf for the purpose of protecting oil shipments through the Strait of Hormuz. Princeton Professor Roger Stern estimated that for the period since the U.S. began guarding Persian Gulf shipping lanes through the year 2010, it has spent about $8 trillion ensuring oil flow to global markets (TIME Battleland, 2011).

D. OPERATIONAL CHALLENGES AND RISKS

The U.S. military's operational energy demand is not only financially challenging, it has become an increasingly complex and risky undertaking to satisfy the "unnecessarily high and growing battlespace fuel demand" (DSB, 2008, p.3). On the battlefield this high demand translates to vulnerable fuel convoys that must provide the last tactical mile of resupply. Fuel and water convoys must move through dangerous territory in the face of improvised explosives and asymmetric forces. During the period of FY 2003–2007 more than 3,000 personnel (U.S. forces and contractors combined) were either wounded or killed in action as a result of attacks on convoys representing approximately half of the total casualties (ASD(OEPP), 2011, p. 5).

Protecting fuel convoys require that combat power be diverted from its primary mission to, instead, the task of guarding and moving fuel. Improvised explosive devices and ambushes are projected to threaten fuel-supplying convoys well into the near future (DOD, 2016 p. 9). When threat conditions become too great a risk to the resupply convoys supporting U.S. forces, military airdrops become the safer way to get fuel and other supplies into remote military outposts. While these airdrops avoid putting ground forces in danger with unnecessarily risky convoys, the financial costs associated aerial resupply to austere areas is significantly higher.

E. STRATEGIC CHALLENGES AND RISKS

There are strategic challenges and risks involved with obtaining energy in a theater of operation. Overseas Contingency Operations are, by definition, operations that occur outside of the United States. Domestic energy supply

sources and domestic refining capacity can do little, if anything, to support U.S. forces abroad. DOD must rely upon energy and logistics interoperability with regional allies and partners, and have the ability to integrate with the global logistics infrastructure, in order to achieve the goals of the National Military Strategy. It is acknowledged that DOD will continue to purchase energy overseas in order to "simplify our supply chains, limit costs, and increase flexibility for the warfighter" (*Energy Security and Research*, 2014).

The pivot or rebalance to the Asia-Pacific region necessitates a far greater reliance upon air and sea mobility and coping with extraordinarily long lines of communication (LOC). As a geographic Combatant Command, the United States Pacific Command (USPACOM) has an assigned area of responsibility (AOR) that spans from the western coast of the United States to the western coast of India, encompassing 36 diverse nations and half of the earth's surface (USPACOM, n.d.). U.S. forces must be able to overcome the tyranny of distance in the USPACOM AOR by first employing its naval and air power, which are also subject to the disruption of fuel supply lines. U.S. forces operating within USPACOM AOR face risks from a wide range of anti-access and area denial (A2/AD) capabilities with the potential to disrupt the energy supply-chain. These A2/AD risks are markedly different and more capable than interdiction threats within the USCENTCOM AOR (DOD, 2016, p. 7).

F. OPERATIONAL ENERGY CONSIDERATIONS IN REQUIREMENTS AND ACQUISITION

Weapons systems have characteristically evolved over time in response to operational needs and in an effort to gain a margin of superiority over a potential threat. Advances in weapons systems capabilities such as lethality, speed, payload, and force protection measures have typically resulted in larger, heavier, and more sophisticated platforms as shown in Figure 4. The second-order effect of a platform's increased size, weight, or complexity is the requirement for additional operational energy.

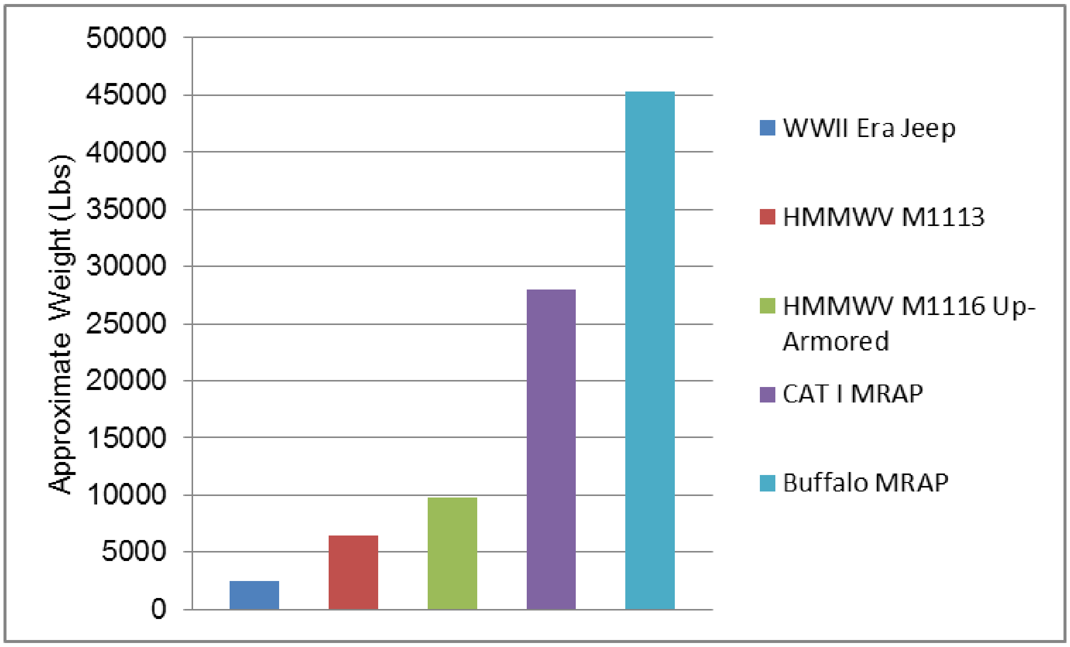


Figure 4. Military Vehicle Weights

As recently as May 2011 the Deputy Secretary of Defense acknowledged that DOD treated operational energy as a "commodity that will always be readily available, regardless of the strategic, operational, and tactical costs" (ASD(OEPP), 2011, introduction). Consequently, relatively few of the major weapons systems in use today have taken into account the ramifications of operational energy dependency.

Until recently, the processes by which DOD defined its warfighter requirements and acquired its weapons systems often placed a greater priority on performance at the expense of efficiency. It was the Defense Science Board (DSB) in 2001 that first noted in their findings that the performance benefits of efficient weapons platforms "are not valued or emphasized in the DOD requirements and acquisition processes" (DSB, 2001, p. 65). Many next generation weapons systems have been shown to be more energy intensive than their predecessors. For example, real world data has shown that the turbine-powered M1 Abrams third-generation main battle tank consumes roughly four times the fuel of the M60 tank that it replaced (JASON, 2006, p. 41). And

although the AH-64 Apache achieves greater lethality and performance compared to the AH-1 Cobra that it replaced, it also weighs twice as much and has approximately twice the rate of fuel consumption.

For existing platforms the power demands of additional onboard mission equipment such as advanced sensor payloads and communication systems may inadvertently generate additional power loads on the platform, resulting in the need for more fuel. Concept of operations (CONOPS) can also drive an increase in fuel demand. The need for soldiers at the platoon and company levels to rapidly exchange digital information (data and images) with their battalion and brigade headquarters, as well as track friendly and enemy locations, requires advanced networking radio systems. Integrating high-bandwidth networking services into tactical vehicles inevitably leads to continuous radio system operation and the undesirable continuous idling of engines.

Although operational performance considerations will always take priority over energy efficiency in major weapons systems, gone are the days when the far-reaching effects of high levels of fuel consumption can be disregarded by the DOD requirements and acquisition communities. Weapons systems cannot simply be fielded with the responsibility falling to the end user to employ creative techniques to manage fuel consumption. The efficiency of a weapons system must be “designed-in” as part of the requirements and development processes. Inefficient, energy intensive weapons systems create a burden on the logistics system and every operational energy dollar saved can be used to provide additional warfighting capabilities elsewhere. Moving forward, DOD must continue to evolve its forces and capabilities with energy usage and energy logistical support requirements playing a central role in its decision-making and business processes.

III. HOW HAVE THE BROADER OE INITIATIVE, GUIDANCE, AND POLICIES EVOLVED?

This chapter provides an examination of select operational energy related studies, national energy legislation, and guidance that have been issued over the course of the last 15 years in order to examine the key contribution of each study and strategy towards the management of operational energy. This chronological perspective on the still-evolving operational energy management area illustrates where policy formulation and implementation were applied to factor energy into the acquisition decision-making process and improve the energy related characteristics of platforms and weapons systems. To conduct this review, various sources were searched to locate published information on the topics of military fuel efficiency, military energy security, and operational energy initiatives. Targeted internet searches were undertaken to find relevant information on these topics, such as conference presentations, Defense Science Board reports and applicable policy directives.

A. OE TIMELINE — STUDIES, STRATEGIES, AND POLICIES

There were several actions and studies that occurred that led to the development of the Operational Energy Strategy (OES). This section will address the various strategies and policies that led to this overarching strategy.

1. 2001 Defense Science Board Report Summary

The 1999 memorandum from the Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) (OUSD[AT&L]) to the Chairman of the Defense Science Board (DSB) requested that a task force be formed to study and report on technologies that improve the fuel efficiency of land, air, and naval platforms. This DSB Task Force, formed for the purpose of improving fuel efficiency of weapons platforms, ultimately published its findings in a January 2001 report titled *More Capable Warfighting through Reduced Fuel Burden*. In addition to identifying numerous technologies with the potential to improve

military energy performance, the 2001 DSB report represents the first effort to characterize institutional barriers that result in the fielding of inefficient weapons platforms and the resulting high demand for operational energy. Because of its findings and recommendations, this 2001 DSB report is often cited in subsequent studies related to military fuel efficiency and operational energy.

During the course of their study, the DSB Task Force uncovered systemic problems in how DOD goes about the business of acquiring weapons systems and this is reflected in its overall findings and recommendations. The DSB Task Force concluded that the issues associated with high levels of operational fuel consumption can be both directly and indirectly attributed to inadequacies in the requirements-setting and acquisition processes. Specifically, the 2001 DSB Task Force made the following summarized findings in their report.

a. Finding 1: Fuel efficiency is not valued or emphasized in the DOD requirements and acquisition processes

The DSB Task Force found that DOD frequently placed the most importance on operational performance and reliability when acquiring weapons systems, overlooking the substantial operational benefits that could be achieved through greater efficiency. Combat effectiveness improvements, such as extended range or higher endurance, can be realized by fielding systems with reduced fuel demand with the additional benefit of less reliance on forward arming and refueling points. The DSB Task Force also noted that DOD did not possess the analytical means to quantify the contribution of energy efficiency to mission performance or what efficiency provided in terms of reductions in logistics requirements. Finally, the DSB Task Force determined that the establishment of an energy-related key performance parameter (KPP) was needed to drive energy efficiency improvements, and that this KPP should be explicitly included in the requirements documents for all platforms.

b. Finding 2: The true cost of fuel is not factored into decision-making

The commodity price of fuel is the direct price that the Defense Logistics Agency (DLA) pays to purchase a gallon of fuel. The DSB Task Force found that DOD's acquisition processes had historically only considered the DLA commodity price of fuel, ignoring the true cost of fuel as delivered in an operational environment. The unavoidable indirect costs associated with the transportation, storage, and protection of fuel had not been factored into DOD's decision-making. These indirect costs associated with the protection and transportation of fuel to forward operating locations, combined with the commodity price of fuel, results in the true delivered cost of fuel for the military also known as the Fully Burdened Cost of Fuel (FBCF). The FBCF can easily be several times higher than the artificially low commodity price of fuel. If the FBCF is not understood, then total ownership costs of a weapons system cannot be calculated and the burden to the military's logistics infrastructure cannot be assessed. Also in the case of existing systems, it is unlikely the case can be made for efficiency upgrades (such as turbine engine retrofits) if only the commodity price of fuel is considered during cost-benefit analyses. The DSB Task Force also noted that DOD lacked the analytical tools and techniques necessary to adequately perform FBCF analysis.

c. Finding 3: Resource allocation and accounting processes do not reward fuel efficiency or penalize inefficiency

The DSB Task Force found that DOD had no means of measuring or quantifying the benefits of managing fuel consumption of weapons systems, therefore fuel efficiency had no significant influence in resource allocation. This inability to quantify fuel efficiency benefits precluded DOD from employing mechanisms to serve as either positive or negative reinforcement on the institutional practices of the acquisition community. Therefore, the planning, programming, and budgeting system (now known as PPBE) could not be used to ensure that appropriate initiatives to achieve efficiency were programmed,

budgeted, or executed. The DSB Task Force also found that DOD's present energy efficiency efforts were primarily limited to achieving compliance with existing federal mandates and executive orders regarding energy use by installations and non-tactical vehicle fleets. At the time none of the existing federal energy mandates or executive orders was articulated in terms of military operational energy, therefore DOD had no real mandates to address or reduce its operational energy usage.

d. Finding 4: Fuel requirements modeling is not linked to requirements development or acquisition program processes

Finding 4 speaks to the lack of a standardized role that fuel logistics played in DOD war-gaming and analytical modeling, which ultimately contributed to inefficient energy usage during operations. Because DOD was not considering the total cost associated with supplying fuel to its forces, it could not integrate this energy information into its war-gaming activities. Therefore, DOD could not estimate the logistics reductions that could be realized by more efficient platforms (such as less demand for fuel) or the potential reduction in total platforms on the battlefield (such as fuel trucks). The DSB Task Force also reasoned that if DOD treated energy as a resource constraint during its campaign modeling and war-gaming processes, it would help uncover the impacts to battlefield fuel logistics and vulnerabilities to the fuel supply chain. Knowledge of fuel logistics vulnerabilities could then be utilized to mitigate these risks before they occur on the battlefield.

e. Finding 5: High payoff, fuel-efficient technologies exist now (i.e., 2001) to improve warfighting (operational) effectiveness

And finally, the DSB Task Force reviewed the availability of existing technologies to improve platform fuel efficiency. The DSB Task Force determined there were existing technologies that, if leveraged for use by DOD weapons systems, would incrementally reduce operational energy demand. The DSB Task Force took a look at previous studies such as the B-52 re-engining study which

showed the potential to reduce USAF tanker force structure requirements. But because of DOD's inability to properly evaluate the future paybacks of increased energy efficiency and the contribution to overall operational effectiveness, the economic case for re-engining the B-52 was not made and near term costs concerns prevailed. Only by fully understanding the true cost of fuel is it possible to propose economically feasible modifications, conversions, and upgrades to fuel intensive weapons systems.

From its findings, the DSB Task Force (2001) formulated five principle recommendations for how DOD can manage the challenges and risks associated with fuel intensive systems:

- Recommendation 1: Base investment decisions on the true cost of delivered fuel and on warfighting benefits.
- Recommendation 2: Link warfighting capability and fuel logistics requirements through war-gaming and new analytical tools.
- Recommendation 3: Provide leadership that incentivizes fuel efficiency throughout DOD.
- Recommendation 4: Specifically target fuel efficiency improvements through S&T investment and systems designs.
- Recommendation 5: Explicitly include fuel efficiency in requirements and acquisition processes. (DSB, 2001, pp. 73–81)

These five DSB Task Force recommendations for improving the fuel efficiency of weapons platforms can be summed up as follows: Substantial financial cost, vulnerabilities, and operational constraints result from the consumption, transportation, and protection of fuel (operational energy) on the battlefield. These are all critical considerations, which must be factored into the requirements development and acquisition decision-making processes for DOD weapons systems.

2. 2007 AT&L Memo on FBCF

In early 2007 the President of the United States issued Executive Order (EO) 13423, *Strengthening Federal Environmental, Energy, and Transportation*

Management, a mandate addressing the government's energy consumption. EO 13423 established goals for federal energy efficiency and instructed all agencies to conduct their energy-related activities in a manner that is economical, efficient, and sustainable. In direct response to EO 13423, OUSD [AT&L] released the 2007 AT&L policy memorandum (*Fully Burdened Cost of Fuel Pilot Program*), which stated, "It is Department of Defense (DOD) policy to include the fully burdened cost of delivered energy in trade-off analyses conducted for all tactical systems with end items that create a demand for energy and to improve the energy efficiency of those systems, consistent with mission requirements and cost effectiveness" (OUSD [AT&L], 2007). At the time, the implementation of the FBCF cost estimating methodology and calculations as a direct contributor to a program's Total Ownership Cost (TOC) had yet to be fully developed. Three programs were identified by OSD [AT&L] to serve as pilot programs to aid in FBCF cost estimation methods and standards development. This OSD [AT&L] FBCF memorandum also prompted issuance of new DOD instruction (DODI), 5000.02, calling for an FBCF analysis to be conducted as part of the Analysis of Alternatives (AOA), Material Solution Analysis phase, of the Defense Acquisition System process (Dubbs, 2011, pp. 5–6).

3. 2008 Defense Science Board Report

A 2006 memorandum from OUSD [AT&L] to the Chairman of the DSB requested that a second task force be formed to "find opportunities to reduce DOD's energy demand, identify institutional obstacles to their implementation, and assess their potential commercial and security benefits to the nation" (DSB, 2008). This DSB task force ultimately published its findings in a February 2008 report titled *More Fight – Less Fuel*. Overall, this follow-up to its 2001 study presented similar findings to those found in its first study. The DSB final report concluded that DOD's operations suffer from "unnecessarily high and growing battlespace fuel demand" that "compromises operational capability and mission success." This conclusion formed the basis of several of the DSB Task Force's findings and recommendations. To put the DSB Task Force findings in context, it

is worth noting that the timing of this 2008 report coincides with peaking in-country troop levels in Iraq and Afghanistan (peak troop level for both wars was reached in FY2008 at 187,900 uniformed military members on ground) (Belasco, 2009, p. 9). The 2008 DSB Task Force converged on six key findings, with the following three findings determined to be of most relevance to this chapter:

a. Finding 1: Recommendations from the 2001 DSB Task Force Report have not been implemented

The 2008 DSB Task Force observed that the recommendations from its previous study on military fuel efficiency had not been adopted by the DOD community and confirmed that those previous findings and recommendations were still valid. Specifically, the DSB Task Force found that DOD had made little progress toward establishment of an energy efficiency key performance parameter (KPP) to address the demand for fuel in mobility platforms. The DSB Task Force (2008) also noted that DOD still needed to develop and implement a fully burdened cost of fuel methodology to better inform its acquisition investment decisions (DSB, 2008, p. 3).

b. Finding 2: DOD lacks the strategy, policies, metrics, information, and governance structure necessary to properly manage energy risks

The absence of strategic energy governance was a key theme in the 2008 DSB's report. DOD did not have a coherent and unifying operational energy strategy and lacked the policies and resource oversight to focus its disparate energy initiatives. DOD also lacked a designated central authority to oversee the implementation of a comprehensive department-wide energy strategy. The lack of a DOD-wide authority providing oversight of the Department's operational energy strategy hindered progress and was deemed to be the root cause of DOD's energy problem (DSB, 2008, p. 6). Focused leadership, to prioritize, coordinate, and advocate for energy initiatives, was seen as a key driver necessary for effective implementation of the Department's operational energy strategy.

c. *Finding 3: Energy efficient technologies are available now but they are undervalued, resulting in slow implementation and inadequate Science and Technology (S&T) investments*

The 2008 DSB report revealed again that its previous recommendations had not resulted in any changes within DOD. The DSB Task Force reiterated that existing and emerging technologies are available now to achieve greater energy efficiency while increasing combat effectiveness in the theater. But its findings indicated that DOD still lacked the expertise (tools and methods) to systematically evaluate the long-term economic and operational benefits of potential energy efficiency gains. This meant science and technology investment opportunities could not be well understood by risk-adverse senior civilian and military leadership, hampering the adoption of cost-effective technologies (DSB, 2008, p. 64).

The DSB (2008) offered five specific recommendations for its key findings, three of which are relevant to this chapter:

- Recommendation 1: Accelerate efforts to implement energy efficiency Key Performance Parameters (KPPs) and use the Fully Burdened Cost of Fuel (FBCF)
- Recommendation 2: Establish a DOD strategic plan that establishes measurable goals, achieves the business process changes recommended by the 2001 DSB report and establishes clear responsibility and accountability
- Recommendation 3: Invest in energy efficient and alternative energy technologies to a level commensurate with their operational and financial value. (DSB, 2008, pp. 65–71)

4. Duncan Hunter National Defense Authorization Act for FY 2009

The Duncan Hunter National Defense Authorization Act (DH NDAA), enacted into public law by Congress in October 2008, levied several important mandates upon DOD with the express purpose of improving the way DOD manages operational energy. This legislation directed DOD to consider fuel logistics support requirements in its program planning, required capabilities determination, and acquisition processes. In particular, the DH NDAA reinforced

the need for DOD to implement an energy efficiency KPP and FBCF analysis on fuel consuming systems in order to manage energy costs and operational impacts. Section 332, paragraph (g) of the DH NDAA provided a legal definition of FBCF as “the commodity price for fuel plus the total cost of all personnel and assets required to move and, when necessary, protect the fuel from the point at which the fuel is received from the commercial supplier to the point of use” (Duncan Hunter National Defense Authorization Act, 2008).

Previously, the 2008 DSB report concluded that no single individual had ultimate responsibility for all aspects of DOD’s energy policy or championing its energy initiatives (DSB, 2008, p. 6). In response to this lack of a strategic change agent, the DH NDAA directed DOD to establish a Director of Operational Energy Plans and Programs position (essentially an “Operational Energy Czar”) to provide the strategic leadership influence necessary to bolster the energy security of the services. This position, which became known as the Assistant Secretary of Defense for Operational Energy Plans and Programs (ASD(OEPP)) (which was later reorganized into Assistant Secretary of Defense for Energy, Installations, and Environment ASD(EI&E)) was tasked with promoting “the energy security of military operations through guidance for and oversight of Departmental activities and investments” (ASD (OEPP), 2011, introduction).

The DH NDAA also directed DOD to develop and implement an operational energy strategy to guide the Department in how to better use energy resources to support its strategic goals while simultaneously supporting National energy security goals. DOD would be required to update this operational energy strategy every five years. Finally, the DH NDAA included a requirement for DOD to submit an annual report to Congress detailing progress made on the implementation of the unifying operational energy strategy.

In summary, the Duncan Hunter NDAA mandated that DOD:

- Calculate the fully burdened cost of fuel (FBCF) for use in acquisition decisions

- Provide leadership to the department and armed services for operational energy plans and programs
- Devise and implement an operational energy strategy
- Submit reports to Congress on operational energy management initiatives and progress

5. 2010 Quadrennial Defense Review

The 2010 *Quadrennial Defense Review* (QDR), a statutorily mandated document outlining DOD's strategy and priorities, directed the services to incorporate operational energy considerations into their force development, warfighting capabilities determination process, and during acquisition processes, highlighting that energy efficiency serves as a force multiplier (DOD, 2010, p. 87). Specifically, it mandated that the services "will fully implement the statutory requirement for the energy efficiency Key Performance Parameters and fully burdened cost of fuel set forth in the 2009 NDAA" (DOD, 2010, p. 87). The 2010 QDR also advanced the concept of military energy security as critical element of national security. The QDR defined military energy security as "assured access to reliable supplies of energy" and acknowledged that a reduction in energy consumption also serves as a means to achieving greater military energy security (DOD, 2010, p. 87).

B. COMPARISON OF THE 2011 OE STRATEGY TO THE 2016 OE STRATEGY

This section will provide an introduction to the comparison of the 2011 OE strategy to the 2016 OE Strategy.

1. 2011 OE Strategy

With the strategic guidance from the 2010 QDR serving its foundation, ASD(OEPP) published its initial operational energy strategy. Released in 2011 as *Energy for the Warfighter: Operational Energy Strategy*, this document set the overall direction for operational energy security for the DOD and the services and satisfied the statutory requirements of Title 10 U.S.C. § 2926(b). The purpose of

the strategy was to guide the strategic use of energy in current and future operations, reduce the risks associated with energy-intensive operations, and provide a cost savings to the American taxpayer. A three-pillar approach was outlined in the Operational Energy Strategy with the following high-level outcomes:

- More fight, less fuel: Reduce the demand for energy in military operations
- More options, less risk: Expand and secure the supply of energy to military operations
- More capability, less cost: Build energy security into the future force. (ASD (OEPP), 2011, p. 1)

These objectives were intended to result in the coherent reduction in operational energy demand, improvements in combat effectiveness, and reduction in military mission risks by less frequent refueling and reduced vulnerability of supply lines.

OEPP published the Operational Energy Strategy's corresponding Implementation Plan (OESIP) in March 2012. This more detailed and comprehensive implementation plan was a necessary follow-up to the generally vague Operational Energy Strategy. The OESIP assigned responsibilities for key tasks and specified milestones and reporting requirements to the services, providing accountability and converting the strategy into action.

2. 2016 OE Strategy

The U.S. policy shift to the Asia-Pacific region, referred to as the pivot (or rebalance) to Asia, is in response to China's rising regional influence and expansionist foreign policy. To address this shift in policy, the 2014 QDR directed the services to prepare for an array of new security challenges as it DOD shifts additional capability and greater military capacity towards the USPACOM Theater. The Office of the Assistant Secretary of Defense (Energy, Installations and Environment) (OASD(EI&E)) released an updated operational energy strategy within the context of the shift to the Asia-Pacific region. The recently

approved 2016 Operational Energy Strategy acknowledged that committing more military resources to the Asia-Pacific region necessitated a relook of the operational energy priorities first published by ASD(OEPP) in 2011. The 2016 version of the Operational Energy Strategy recognizes that the availability of operational energy will continue to present a challenge for U.S. power projection, and continues to view efficiency through the lens of military utility and operational effectiveness. Because of the inherently long distances associated with operating within the Asia-Pacific region, DOD acknowledges it is facing an increased reliance upon on naval fleets and aviation, which require more fuel than the ground-oriented operations in the USCENTCOM Theater. Also, potential adversaries in the Asia-Pacific region have the ability to employ sophisticated anti-access and area denial (A2/AD) capabilities, which can threaten the assured delivery of energy to U.S. forces. In order to meet these new and enduring operational energy challenges, the 2016 strategy states DOD will pursue the following broad objectives:

- Increase future warfighting capability by including energy throughout future force development
- Identify and reduce logistics and operational risks from operational energy vulnerabilities
- Enhance the mission effectiveness of the current force through updated equipment and improvements in training, exercises, and operations (OASD EI&E), 2016, p. 10)

The 2016 Operational Energy Strategy asserts that DOD has steadily improved its understanding of the operational energy domain in order to ensure the warfighter has the energy necessary to perform critical global missions. One of the ways DOD has accomplished this is through improved analytical capability to better understand the implications of energy use in force development. To achieve the first objective of the 2016 Operational Energy strategy, DOD recognizes the services must continue to institutionalize Energy Supportability Analyses (ESA) early in the required capabilities determination and acquisition processes. ESAs were first mandated by the FY2015 NDAA Joint Explanatory

Statement, which directed DOD to consider the operational impact of energy logistics through the conduct of an energy supportability analysis. An ESA facilitates the identification of energy shortfalls and is used to inform the Energy Key Performance Parameter, which is now being enforced for all energy consuming military systems.

The 2016 Operational Energy Strategy also affirms that DOD is committed to develop and acquire the technologies that improve the long-term energy performance of weapons platforms. These technologies may include better or new means of propulsion such as advanced turbine engines. The strategy also addresses improvements to the operational energy performance of existing equipment, particularly systems that consume significant amounts of energy and are fielded in sufficient numbers. DOD's progress in achieving its strategy objectives will be monitored using existing mechanisms, such as the annual PPBE cycle, Joint Requirements Oversight Council, and the Defense Acquisition Board process.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. MATURING PLANS, PROCESSES, AND MECHANISMS WITHIN THE ACQUISITION SYSTEM AND THE DESIRED EFFECT

Is the Operational Energy strategy gaining traction? Operational energy is defined in law as, “the energy required for training, moving, and sustaining military forces and weapons platforms for military operations. The term includes energy used by tactical power systems and generators and weapons platforms” (DOD, 2016, p. 3). We intended to identify areas of strength and weakness within the DOD acquisition process that highlight a strategic shift in policy, and more importantly a shift in actual practice or progress by the United States military services. We started our analysis with a new Army program, as an example that the OE strategy appears to be gaining traction. Then we reviewed the major acquisition law, regulations, policy and guides to assess if the OE strategy has made its way into these key documents.

A. DESIGNING FUEL EFFICIENCY TO REDUCE FUEL CONSUMPTION: U.S. ARMY IMPROVED TURBINE ENGINE PROGRAM (ITEP)

The U.S. Army is making progress in the aviation community that should significantly reduce its reliance on fuel while filling noted capability gaps within the Army helicopter fleet. The Army states that its Improved Turbine Engine (ITE) shall replace all engines currently fielded in U.S. Army Black Hawks, H-60, and Apaches, AH-64, shown in Figure 5. It highlights in the ITE Acquisition Strategy that the ITE shall be a form, fit replacement for the T700 General Electric series engine (701D), so that the new engine can fit within the existing engine compartments of both the H-60 and AH-64E (Program Executive Officer, Aviation, 2015, p. 9). Moreover, the new ITE shall provide significantly more power (i.e., 3000 Shaft Horse Power) while reducing fuel consumption and decreasing sustainment costs. The ITE Analysis of Alternatives (AOA) was approved in June 2014 and the Acquisition Strategy approved in August 2015.

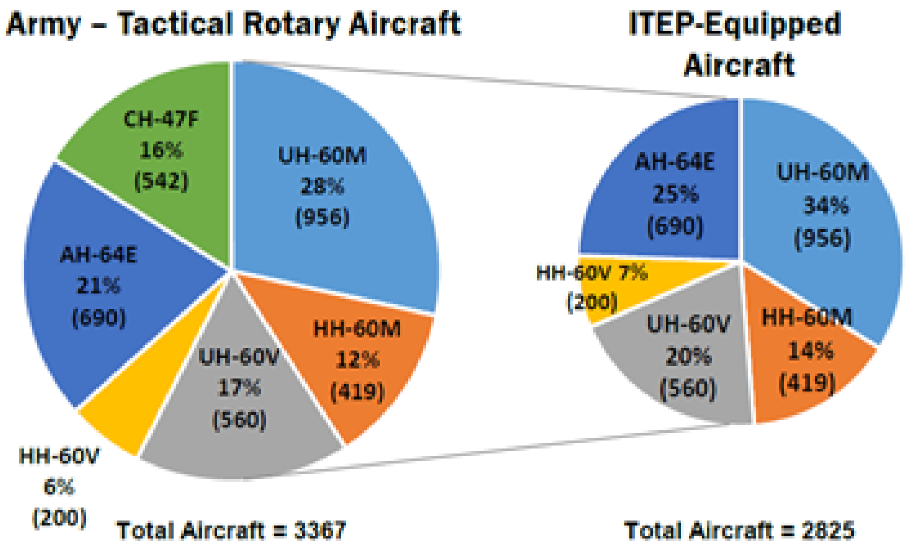


Figure 5. ITEP-equipped Aircraft as a Percentage of Total Army Aircraft. Source: Program Executive Officer, Aviation (2016).

The ITE program office successfully completed the Milestone A review with the Army Acquisition Executive and the Army Requirements Oversight Council (AROC) with the Chief of Staff of the Army in the third quarter of fiscal year 2016. The ITE Program now enters into the technology maturation and risk reduction (TMRR) acquisition life-cycle phase in an effort to identify and leverage existing technologies to improve performance, of course, but also reduce fuel consumption, in response to the new E-KPP. Figure 6 depicts the DOD acquisition life-cycle phasing/milestone summary. The Army Acquisition Product Manager for the ITE can now award two contracts to produce preliminary engine designs to achieve the 25% “Objective” Energy-Fuel efficiency requirement.

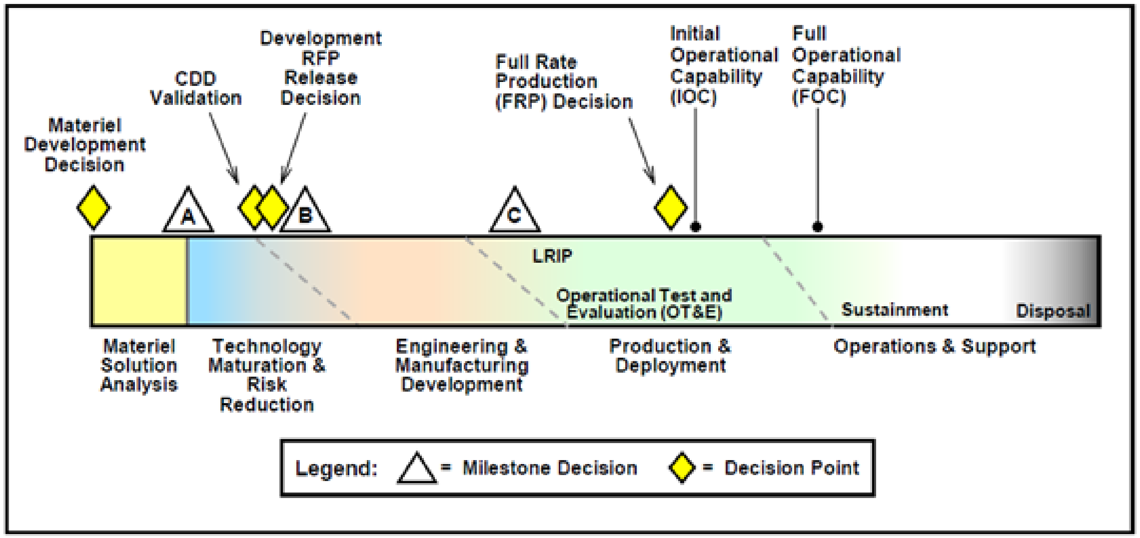


Figure 6. Model 1, Hardware Intensive Program. Source: OUSD(AT&L) (2015), p. 9.

Complex design efforts typically include tradeoff analysis and selection of the best value solution, balancing performance with cost and other key factors. It is important to note that there are second-order effects to changing propulsion and energy systems within already fielded systems, like the Army plans to do with Black Hawks and Apaches. Retrofitting an older engine with a new, more powerful, and higher fuel efficiency rated engine may seem simple on the surface, yet in practical terms be highly complex and costly. The average fuel consumption will be reduced in most operational environments, but will total ownership costs (TOC) for Army Aviation be reduced? As shown in Figure 7, for legacy aircraft such as Apaches and Black Hawks, which were designed for lower shaft horsepower (SHP) engines (2000-SHP General Electric T700s), the TOC might go up due to a more the powerful engine causing additional stress, strain, and fatigue on a legacy fuselage, drive system, and support components. These higher forces may reduce the life of some legacy aircraft components, commonly referred to as flight safety parts that were designed for lower forces and less stress. Many aircraft parts have a designed fatigue life. Once a part has reached its usable life, then aviation maintenance planners are required to

replace worn-out parts to ensure reliability and safety standards. Further detailed design and cost analysis will be required to understand the effects of these different forces and determine if redesign efforts are required on these legacy components. There are also potential cost increases in the operations and support (O&S) acquisition life cycle phase, because maintenance personnel may have to replace these components more often due to the increased forces exerted by the higher SHP engine propulsion systems. This example drives home the need for high-fidelity fully burdened cost of energy (FBCE) modeling and simulations to accurately inform decision makers of holistic total-life of the system TOC estimations.

ITE AoA Alternatives

	Material Solution	Max Power (MRP shp, Sea level 59°F uninstalled)	Fuel Burn (lb/hr, at 1300 shp, Sea level, 59°F, uninstalled)	Weight (lbs)	Design Life (hrs)
Alt 1	Currently fielded engine: (T700-GE-701D)	~2000	~630	456	5000
Alt 2	Derivative of -701D engine	▲+120	▼-2% (~620)	NC	NC
Alt 3	COTs/GOTs engine: 3A: GE YT706 (MH-60M) 3B: Turbomeca RTM322 (UK WAH-64D)	▲+600 ▲+800	▲+4.4%(~660) ▲+3.3%(~655)	▲+100	NC
Alt 4	ITEP/New Start Development	▲+1150	▼-12%(~560)	NC	▲+1000

ITEP / New Start Development the only solution to address performance capability gaps at 6 thousand feet and 95 degrees (high/hot)

Figure 7. ITE Analysis of Alternatives. Source: Army Material Systems Analysis Activity (2014).

Overall, the Army's Improved Turbine Engine Program appears to be a success story in the making, because the Army is implementing the new Energy Key Performance Parameter (E-KPP) that will reduce fuel consumption or demand in 2,825 Army legacy aircraft.

B. FULLY BURDENED COST OF ENERGY

Fully Burdened Cost of Energy is defined and explained in U.S. Law Title 10 U.S.C. § 2911. A Defense Acquisition University reference, *Defense Acquisition Guidebook* (DAG), website chapter 3.1.6, summarizes FBCE as a holistic or systematic attempt to capture as many costs as possible, related to the fuel supply chain, including the cost of delivery and associated force protection requirements as shown in Figure 8. The DAG provides a comprehensive description of DOD current thinking and progress toward using FBCE modeling. The *Defense Acquisition Guidebook* (DOD, 2013) makes the point that the expanded use of FBCE modeling is critical to understanding weapon system effectiveness and total costs in a wartime scenario as measured in dollars, distance, and lives (p. 15).

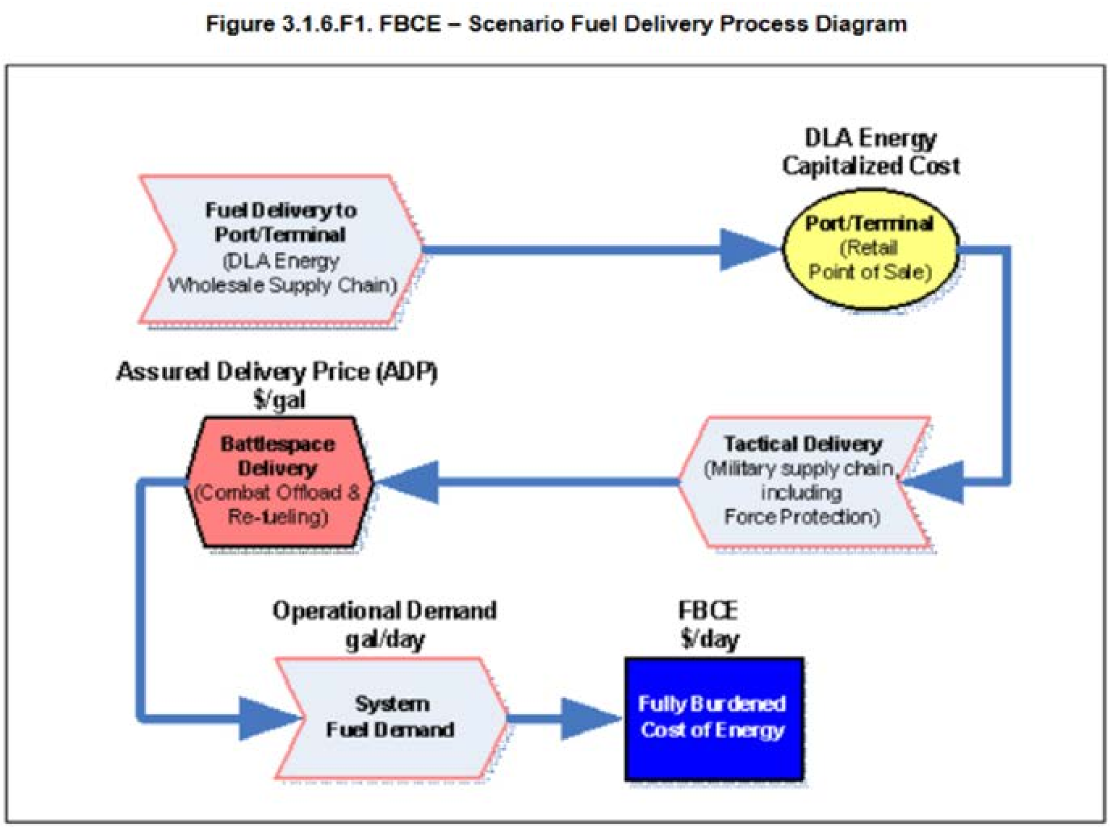


Figure 8. FBCE Fuel Delivery Process Diagram. Source: DOD (2013), Section 3.1.6.

C. EVOLUTION OF THE DOD ACQUISITION SYSTEM TO SUPPORT GREATER VISIBILITY AND SENSITIVITY TO ENERGY AND FUEL CONSUMPTION

First, a brief overview should be presented of the three overlapping and interdependent systems used by DOD to deliver warfighting capability, as reflected in Figure 9. In the “Big A Concept and Graph,” DOD shows three principal decision-making support systems. This support system is used by the DOD to strategically plan for required capability need assessments, procurement of weapon systems, and program resourcing.

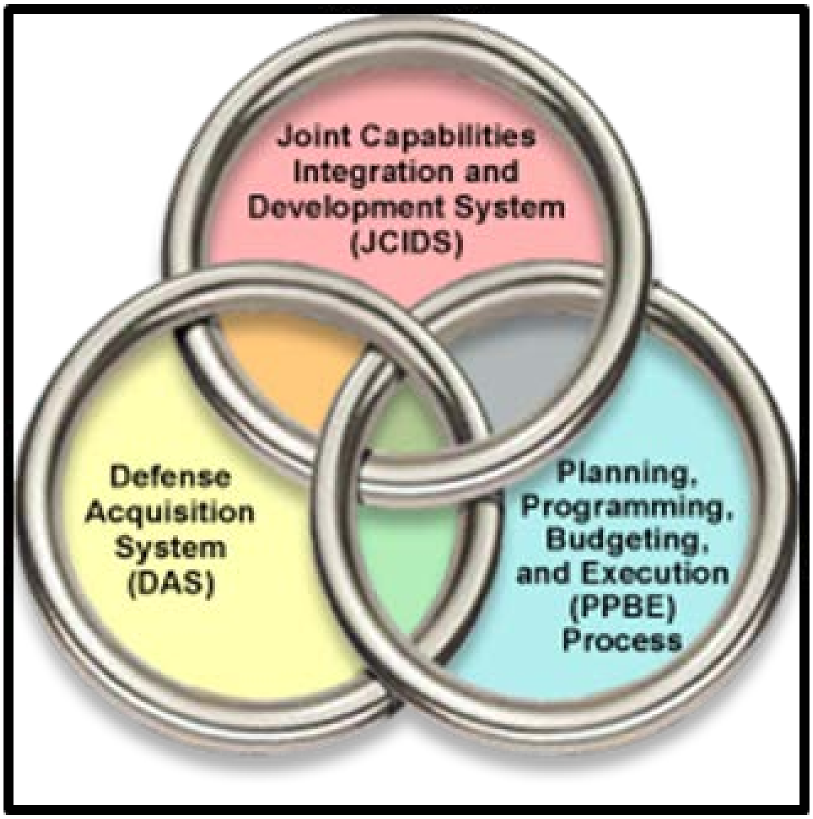


Figure 9. The “Big A” DOD Decision Support System. Source: Defense Acquisition Portal, https://dap.dau.mil, retrieved June 26, 2016.

The acquisition process as documented in DODI 5000.02 was last updated January 7, 2015, and articulates policy for the management of all acquisition programs (OUSD(AT&L), 2015). This instruction defines the process,

decision milestones, deliverables, oversight, and reporting requirements for all DOD acquisition programs. The yellow circle in Figure 9 represents this process. Each service has Program Executive Offices organized by common mission areas, which are led by a general or flag officer and oversee program offices typically led by a colonel or Navy captain. They oversee the execution of the system acquisition and perform the major tasks of cost estimation, budget development, contracting/procurement, systems design, development, logistics support strategy, test, training development, and ultimately fielding of the weapon and information management systems.

The Joint Capabilities Integration and Development System (JCIDS) process is documented in CJCSI 3170.01I, dated 23 January 2015. The process exists to support the Joint Requirements Oversight Council (JROC) and Chairman of the Joint Chiefs of Staff (CJCS), who have the responsibilities in identify, assess, validate, and prioritize joint military capability requirements. The red circle in Figure 9 represents this process. The JCIDS instruction notes that the output of this process determines system capability requirements which drive the acquisition community to deliver a system with those capabilities. The Defense Acquisition Portal (DAU, 2016) describes the JCIDS as providing a transparent process that allows the JROC and Service Acquisition Requirement Councils, like the AROC did for the ITEP, to make decisions on how capabilities should be prioritized and validated.

Per DODD 7045.14, (ODSD, 2013), the planning, programming, budgeting, and execution (PPBE) process starts from the President's National Security Strategy (NSS), then the Defense Secretary's National Military Strategy (NMS) and associated policy guidance to dictate the planning phase. These high-level documents guide the mid-range programming efforts, led by the Director for Cost Assessment and Program Evaluation (DCAPE) to identify capability gaps and materiel solutions for prioritization and programming. The services work closely with the Office of Secretary of Defense (OSD) to influence the president's annual budget during the budgeting phase. Following

Congressional authorization and appropriation actions and presidential signatures, the Service Acquisition Executives and Program Executive Officers (PEOs), along with their Program Offices, execute defined programs to deliver weapon and information management system capabilities to address gaps highlighted in the NSS and NMS's. The blue circle represents the PPBE process in Figure 9.

1. The Evolving Acquisition Management Process — "The Yellow Circle"

Prior to its formal January 2015 release, the last major approved release of DODI 5000.02 was December 2008. Enclosure 7, sections 5 and 6, contained only two short directives pertaining to energy. The first was for the Director, Program Analysis and Evaluation (DPA&E) to ensure the AOA followed their study guidance and assessed, "alternative ways to improve the energy efficiency of DOD tactical systems with end items that create a demand for energy, consistent with mission requirements and cost effectiveness." The second, contained only one sentence, "6. ENERGY CONSIDERATIONS. The fully burdened cost of delivered energy shall be used in trade-off analyses conducted for all DOD tactical systems with end items that create a demand for energy."(OUSD[AT&L], 2008). , Enclosure 7, section 6 p. 59)

The Defense Science Board Task Force on DOD Energy Strategy was just completing its 2008 report, *More Fight Less Fuel*. Thus, DODI 5000.02, the key acquisition process document, would not see another update for a full five years, until the interim release on November 25, 2013. This update only slightly modified the call for AOAs to include, "(g) considers the fully burdened cost of energy (FBCE) where FBCE is a discriminator among alternatives" ((OUSD[AT&L], 2013), enclosure 9, section 2.c(1)(g), p. 123). This statement seems to give the impression that when all other factors are equal, then FBCE modeling can be used to determine the best course of action. The authors of this research report consider this very weak guidance that would have little to no effect on behavioral change within the DOD to reduce reliance on fuel.

The 2008 DSB report noted two primary challenges: 1) high and growing demand for fuel in today's weapon systems compromises our capabilities, threatens supply chain support personnel, and mission success, and 2) that installations with heavy reliance on energy and fuel are increasingly vulnerable. During a brief to the 2008 DSB task force, Gen James T. Mattis, USMC, said, "Unleash us from the tether of fuel" (Bochman, 2008). So the question remains, how did this DSB study and other findings and defense reviews influence the most recent DODI 5000.02, published in January 2015?

The January 2015 version of DODI 5000.02 provides four template schedule models to generically apply and tailor to a given acquisition program, whether hardware or software intensive. The 2015 Instruction gives acquisition professionals and decision makers leeway to tailor deliverables and decision milestones. The authors of the instruction removed the statement requiring that the DPA&E ensure study guidance addressed: "Alternative ways to improve the energy efficiency of DOD tactical systems with end items that create a demand for energy, consistent with mission requirements and cost effectiveness." The only statement that remains within the latest DODI 5000.02 of January 2015 pertaining to energy is the same as in the 2008 release, "Consider the fully burdened cost of energy (FBCE), where FBCE is a discriminator among alternatives" (OUSD[AT&L], 2015).

It is disappointing that the current DODI 5000.02 does not take into account any of the findings or recommendations from the DSB, 2011 Operational Energy Strategy, or the 2014 QDR, which states, "Energy improvements enhance range, endurance, and agility, particularly in the future security environment where logistics may be constrained." (DOD, 2014). Also, the NSS of February 2015 indicates a global strategic shift to the Pacific region where supply chain dynamics (fuel, parts, and personnel) will be that much more strained, complex and difficult than the current USCENTCOM area of operations (AO). This future challenge supports our concerns that DOD requirements and acquisition leadership has to be looking to mitigate these growing risk by

reducing our reliance of fossil fuel. Moreover, the 2016 Operational Energy Strategy reiterates that operational energy presents an increasing national and defense vulnerability as our forces continue to have a greater reliance on fuel and are required to operate with longer and more vulnerable supply lines (DOD, 2016).

After review of some of the key national strategies, studies, and acquisition process documentation, the authors of this report conclude that the initiative to reduce reliance on fuel, quite clearly, has not gained tangible traction within the acquisition process.

a. Cost Assessment and Program Evaluation (CAPE)

The CAPE Director and associated team were established in 2009 as part of the Weapon Systems Acquisition Reform Act (WSARA). The Director, CAPE works directly for the Secretary of Defense, and oversees the Programming phase of the PPBE, mentioned above. The Director, CAPE is a major player and voting member at all Defense Acquisition Boards and major milestone reviews. The CAPE organization serves a powerful role since they essentially support both the PPBE process and the capability requirements process. At a summary level, they serve two primary roles, that of Cost Assessment and Program Evaluation.

(1) Program Evaluation

Since the WSARA-2009 they have taken the role previously performed by the DPA&E, to include the issuance of AOA study guidance. The study guidance is crafted prior to the AOA as a set of directions to steer the work of the AOA, which is a key activity during Materiel Solution Analysis phase. Results of the AOA are reported out to the DAB at MS A. As noted on the CAPE website, the CAPE provides independent analysis and advice to the JROC and OSD staff.

(2) Cost Assessment

To ensure the "Big A" had an independent unbiased analysis and cost assessment view point, as part of WSARA-2009, all Major Defense Acquisition Programs (MDAPs) receive a CAPE-developed and approved Independent Cost Estimate (ICE) at each major acquisition milestone. The Acquisition Milestone Decision Authority will then expect each service (Army, Navy, and Air Force) to agree to fund the program to the levels determined by the CAPE ICE. Prior to WSARA-2009, the service would provide their own service cost estimate as the basis for budget establishment.

b. Operations and Support Cost Estimating

It is worth noting that the CAPE's Operations and Support Cost Estimating Guide 2014 provides some information as to how to capture energy cost, but makes no mention of Fully Burdened Cost of Energy modeling or methods. It bounds or defines the cost estimation method for energy to include fuel, petroleum, oil and lubricants solely in peacetime missions. This is a concern underscored by the 2016 OE Strategy which encourages the use of FBCE calculations and modeling (DOD, 2016). We cannot assume a weapon system will remain effective if planning only includes peacetime operations. We find this to be a major disconnect in understanding total cost and system vulnerabilities. DOD should continue to leverage maturing efforts to understand the true total cost of weapon systems in wartime scenarios which can now be captured via higher fidelity modeling and simulations.

2. Joint Capabilities Integration and Development System (JCIDS) Requirements Process — "The Red Circle"

We transition from the acquisition process to the JCIDS process, or what we will refer to as the "capability requirements process" where user needs and gaps are identified in the context of the current National Security Strategy, and National Military Strategy. User needs are captured, prioritized, formalized, controlled and documented in Initial Capabilities Documents (ICD), Capability

Development Documents (CDD), and then Capability Production Documents (CPD), which feed and drive the Acquisition System discussed above and shown in Figure 10 and Figure 11.

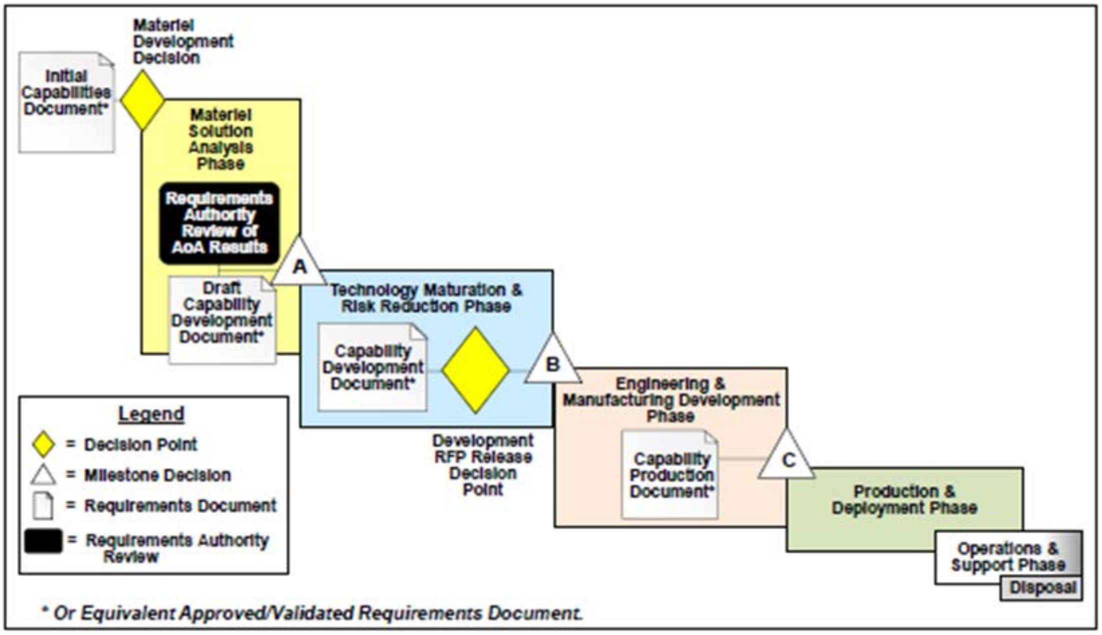
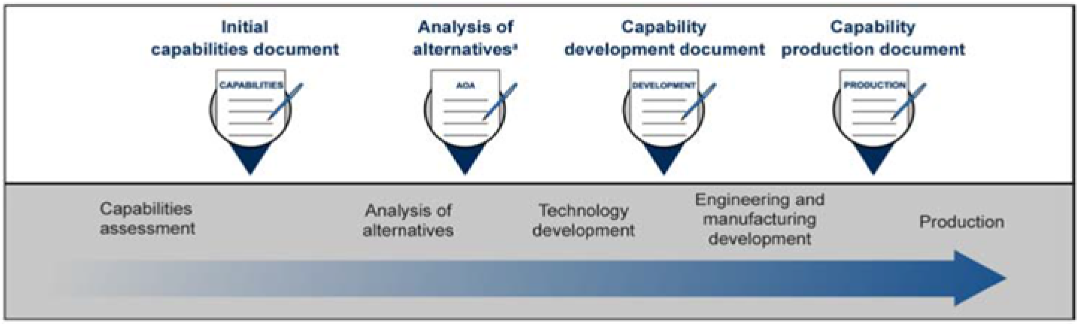


Figure 10. Interaction between JCIDS Capability Requirements Process and Acquisition Process. Source: OUSD(AT&L) (2015), p. 5.

Historically, DOD Program Managers (PMs) working within the Acquisition process have not been incentivized or required to address operational energy usage and/or reduce fuel consumption while meeting system capability requirements documented in the ICD, CDD and CPD. A system would be designed within the acquisition process by the PEO/PMs to meet certain Key Performance Parameters (KPPs) established by the requirements community, tested for operation effectiveness and suitability, and then fielded. If the system consumed fuel at four miles per gallon while meeting key performance parameters, then it left the acquisition domain to enter the supply side infrastructure. Essentially, deployed forces were/are required to work with the Defense Logistics Agency (DLA) to fill gas tanks with an insatiable desire for more.

Figure 1: Interaction between DOD's Requirements Generation and Acquisition Processes



Source: GAO analysis of DOD policy.

[a]The 2012 JCIDS guidance directs the Functional Capabilities Boards to review the analysis of alternatives and other analyses for certain capability requirements. See Chairman of the Joint Chiefs of Staff Instruction 3170.01H, Joint Capabilities Integration and Development System, enc. A, para. 2(c)(1)(b) (Jan. 10, 2012) (hereinafter cited as CJCSI 3170.01H (Jan. 10, 2012)).

Figure 11. How DOD Needs Fit into the Acquisition Process. Source: GAO (2012).

One challenge which limits the DOD in gaining OE traction is the lack of new weapon system program starts due to constrained budgets. Most DOD front line weapon systems were designed 20 to 40 years ago. System upgrades and modifications typically receive much less oversight than new-start programs. This is where the PPBE process could provide greater influence and oversight to ensure modification programs, typically funded with procurement dollars, could be forced to consider second-order effects to fuel reliance and supply infrastructure demands.

As noted in Chapter III, there have been many attempts to raise awareness of this growing issue. As we look at the evolution of the capability requirements process, other factors have been at play, such as the terrorist attacks on the World Trade Center September 11, 2001, erratic costs of fuel due to large swings in fuel supply and demand, increasing threats and vulnerabilities of the supply lines in CENTCOM Middle East region, and now the National Security Strategy focus shift to the PACOM Asian-Pacific region driven by the 2014 QDR. All these factors appear to be raising levels of urgency and

awareness, but are they urgent enough to effect change in the capability requirements process?

The first time the capability requirements process included any mention of the energy efficiency KPP or consideration for Fully Burdened Cost of Energy or Fuel is in JCIDS 3170.01, May 2007. The JROC accepted the recommendations documented in the JROC Memorandum 161-06, August 17, 2006, which called for the inclusion of the E-KPP but only as a “Selectively Applied KPP,” not a mandatory KPP. This memo stresses the need for life-cycle cost analysis for developing new capabilities, yet says nothing about evolutionary acquisition or incremental development. This appears to be shortsighted and supports our concern and combined 50 years’ acquisition experience that once a system has been fielded, and is in an incremental upgrade and modifications stage of the life cycle, program managers are not incentivized or required to reduce reliance on fuel.

The following are the main sections of the JCIDS 3170.01 capability requirements process documents from 2007 through 2015 pertaining to energy. Although we observe some increased awareness and sensitivity in 2007, it is not until 2012 when the requirement became mandatory. The 2015 document is also markedly expanded to include large segments solely addressing the issues of reliance on fuel, supply chain, cost estimates, wartime planning and demand reductions. We have selected key sections in each of the previous versions to highlight main content and action points related to energy.

The authors of this research paper believe that the Duncan Hunter National Defense Authorization Act for FY 2009, 10 USC 2911 § 332, was the key event to drive real change within the DOD to consider fuel demands, burden on the supply chain and costs analysis such as FBCE and FBCF in requirements and associated acquisition.

The CJCSM 3170.01C of May 2007 contained no mandatory KPP or Key System Attribute (KSA) for energy or fuel consumption. It states:

> Include fuel efficiency considerations for fleet purchases and operational plans consistent with mission accomplishment. Life-cycle cost analysis will include the fully burdened cost of fuel during the AOA and subsequent analyses and acquisition program design trades. The fully burdened cost of fuel includes the price of the fuel delivery chain (to include force protection requirements). (p. B-6)

The CJCSM 3170.01 of Feb 2009 states that the 2009 JCIDS process still only notes the energy KPP as “selectively applied” and not mandatory. It states:

> Include fuel efficiency considerations in systems consistent with future force plans and approved planning scenarios. Include operational fuel demand and related fuel logistics resupply risk considerations with the focus on mission success and mitigating the size of the fuel logistics force within the given planning scenarios. These assessments will inform the setting of targets and thresholds for the fuel efficiency of materiel solutions. Consider fuel risk in irregular warfare scenarios, operations in austere or concealed settings, and other asymmetric environments, as well as conventional campaigns [we could not find this paragraph in the 2009 version].

As noted in CJCSM 3170.01 of Jan 2012, this is the first time the JCIDS process lists the Energy KPP as a mandatory performance parameter in materiel solutions meeting noted capability gaps.

> The Energy KPP is applicable to all documents addressing systems where the provision of energy, including both fuel and electric power, to the system impacts operational reach, or requires protection of energy infrastructure or energy resources in the logistics supply chain. The intent of the Energy KPP is to optimize fuel and electric power demand in capability solutions as it directly affects the burden on the force to provide and protect critical energy supplies. The KPP includes fuel and electric power demand considerations in systems, including those for operating “off grid” for extended periods when necessary, consistent with future force plans and ISCs. The Logistics FCB, in coordination with the Joint Staff J-4 / Engineering Division (J-4/ED) and with advice from the Defense Energy Board as appropriate, will assess the Energy KPP, or Sponsor justification of why the Energy KPP is not applicable, for any document with a JSD of JROC or JCB Interest. Additional guidance on the Energy KPP is provided in Appendix H to this Enclosure. (p. BA-3)

As noted in CJCSM 3170.01, Feb 2015, the JCIDS process adds an entire enclosure F (appendix F), which further clarifies the mandatory KPP beyond the 2012 guidance. The appendix provides detailed review criteria, requiring conduct of an Energy Supportability Analysis, determining proper scope, relevance, clarity and measurability. This process has also matured to the point where it arranges analytical support from the Office of the Assistant Secretary of Defense for Energy, Installations, and Environment. The latest JCIDS process notes:

> The Energy KPP is intended to ensure combat capability of the force by balancing the energy performance of systems and the provisioning of energy to sustain systems/forces required by the operational commander under applicable threat environments. The Energy KPP includes, but is not limited to, optimizing fuel and electric power demand in capability solutions, in the context of the logistical supply of energy to the warfighter, as it directly affects the burden on the force to provide and protect critical energy supplies. The Energy KPP includes both fuel and electric power demand considerations in systems, including those for operating ‘off grid’ for extended periods when necessary, consistent with SSA products. In cases where energy demand reduction is impractical or insufficient to align with projected energy supply, complementary DOTMLPF-P changes to the energy supply chain must be addressed in the document to accommodate the increased energy demands and satisfy the Energy KPP. (p. D-A 3, 4)

The CJCSM JCIDS 3170.01 Feb 2015 shows a great many sections and appendices requiring detailed energy analysis and capability trade-offs. The authors of this research project believe the 2015 updated process is now driving the acquisition community to consider energy demands and the risks and vulnerabilities related to its reliance as we see in the Army’s ITEP. It is clear that the capability requirements community is now taking energy very seriously. Since the acquisition process follows the capability requirements process, it should be only a matter of time before weapon systems will evolve to reduce reliance of fuel and energy. Yet this may take a long time, given the time it takes to design, test and field a complex major system.

3. Planning, Programming, Budgeting, and Execution System (PPBE) Funding Process — "The Blue Circle"

The PPBE is a resource allocation or financial management process used within the DOD. This process takes national and military-level strategy and combines planning, programming, and budgeting guidance to produce an annual budget that is submitted by the President, approved by Congress, and then executed by the Military Service PEOs and their program managers as shown in Figure 12. The process is documented in DOD Directive 7045.14, January 2013, and tightly integrated with the acquisition and capability requirements process as discussed above (OSD, 2013).

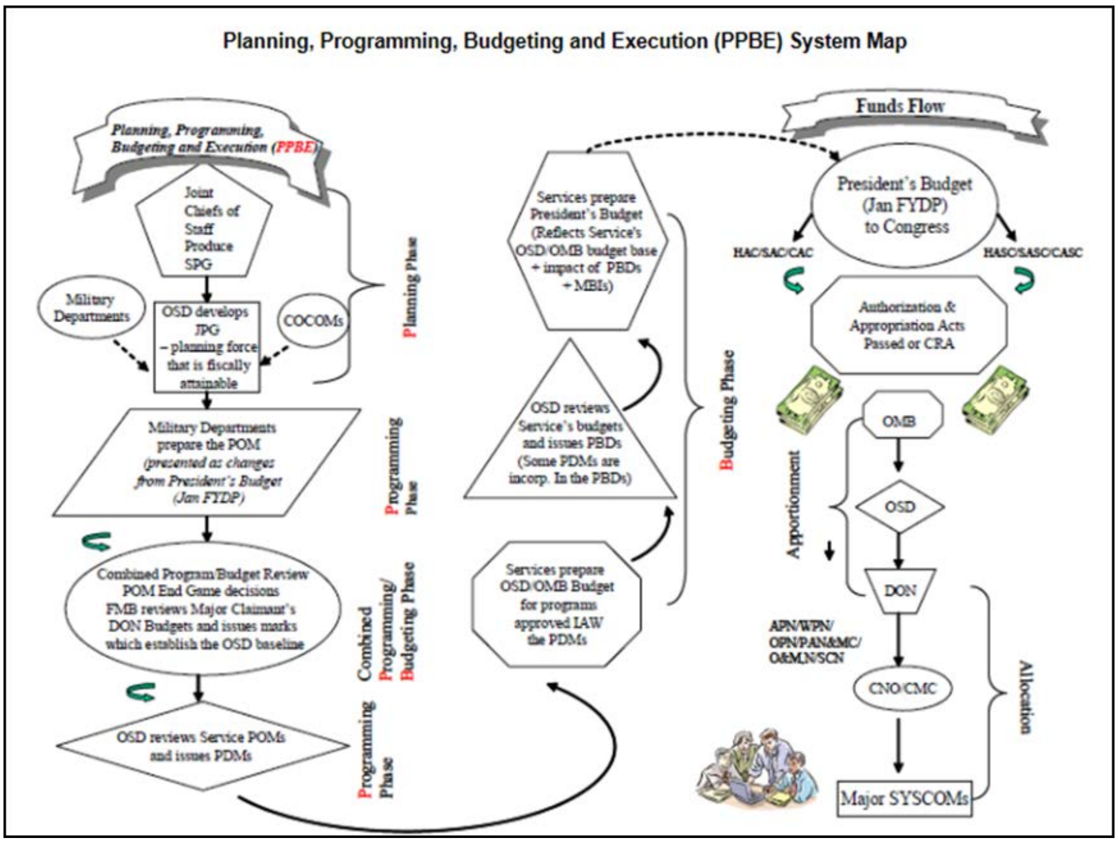


Figure 12. PPBE Process Flowchart. Source: AcqNotes (2016).

We comment above that once a program manager has completed his major Defense Acquisition Board (DAB) milestone reviews and enters into full

rate production and fielding status, much of the oversight within the acquisition process trails off. Yet, year after year the warfighter and capability requirements community continue to look for ways to adapt the weapon system to remain ready and relevant to meet evolving capability gaps. The program manager working with the resource and capability requirements community will request additional funds through the PPBE process to modify and adapt their system, or risk becoming irrelevant and/or obsolete. National defense is a dynamic environment which requires agile and rapid responses to counter enemy tactics, and techniques. However, as we highlight in Chapter II, we cannot continue to ignore the greater and greater dependency on fuel. The enemy is now exploiting this dependency and fuel reliance is becoming a national and system vulnerability.

We assert that most of the front line weapon systems today are well beyond their Full Rate Production (FRP) decision and that DOD relies heavily on weapon system upgrade and modifications, rather than new program starts. The Department needs to look for ways within the PPBE process to incentivize and require reductions in fuel reliance and consumption for these modification programs. The DOD has stressed for some time the application of evolutionary acquisition strategies and incremental development. These approaches have been highly successful, yet the PPBE now needs to adapt to this growing national fuel vulnerability.

V. PROMULGATION AND SYSTEMATIC CHANGE MANAGEMENT STRATEGY

Merriam-Webster defines promulgate as a verb, which simply means to "make an idea or belief known to many people or to make a new law publicly and officially known" ("Promulgate," n.d.) Because the Operational Energy Strategy was conceived, documented, and published as law within the last decade, there is a need to promulgate this strategy so that it reaches all the users and stakeholders that will eventually be affected by it. The 2011 Operational Energy Strategy established the position of Assistant Secretary of Defense for Operational Energy Plans and Programs (ASD(OEPP)). The mission of this position is to "promote the energy security of military operations through guidance for and oversight of Departmental activities and investments." Therefore, this strategy sets the direction for operational energy security for combatant commands, defense agencies, the Office of the Secretary of Defense (OSD), and the DOD components. The initial OES, as published in 2011, provided the overarching guidance to all DOD components with the intent that the strategy and implementation plan would be updated as the Department attained more understanding of current and future operational energy consumption (DOD, 2011).

In 2015, the ASD(OEPP) office and the Deputy Under Secretary of Defense for Installations and Environment office merged to create the Assistant Secretary of Defense for Energy, Installations, and Environment (ASD(EI&E)). The responsibility of this office includes implementation of the overall OES. The first update to the 2011 OES was drafted in December 2015 as a result of significant changes in the DOD and new and enduring challenges within the operational environment. Additionally, the next generation of weapons platforms and concept of operations (CONOPS) have proven to use more energy than their respective predecessors. DOD will utilize the Defense Operational Energy Board (DOEB), chaired by the Joint Staff/Director for Logistics (JS/J4) and the

ASD(EI&E), coupled with the annual PPBE process, to coordinate, review, and prioritize activities and ensure that align to the goals and objectives of the OES (DOD, 2016).

Now that DOD has a better understanding of energy use and its implications in systems, CONOPS, and operation plans (OPLANs), the department is using energy supportability analyses (ESAs) to better support and inform the E-KPP required for specific military platforms. The ESA may identify changes in the design of a system or of a system's energy use as well as identify changes in logistics capacity, force structure, and CONOPS. This improved fidelity in operational and logistical risk identification enables prioritization and precision in specific responses and mitigations. The Department is considering the requirement of operational energy demands be included in Capabilities-Based Assessments (CBAs) prior to the development of E-KPPs. This additional knowledge of energy constraints will ensure that the Department can make better energy-informed decisions (DOD, 2016).

A. AS IT RELATES TO THE SERVICES

Each of the Services has developed its own vision and strategic plan for reducing operational energy dependence.

1. Air Force

The 2013 U.S. Air Force Energy Strategic Plan states that the Air Force accounts for approximately 48% of the total energy consumption for the Department of Defense. As shown in Figure 13, aviation fuel accounts for the vast majority. This is comparable to approximately 2.5 billion gallons of fuel for aviation and 64 trillion BTUs per year, as well as a significant amount of gas emissions. This strategic plan also states that energy costs for the Air Force are approximately $9 billion per year. This amount is expected to increase although fiscal resources are becoming more constrained (U.S. Air Force, 2013).

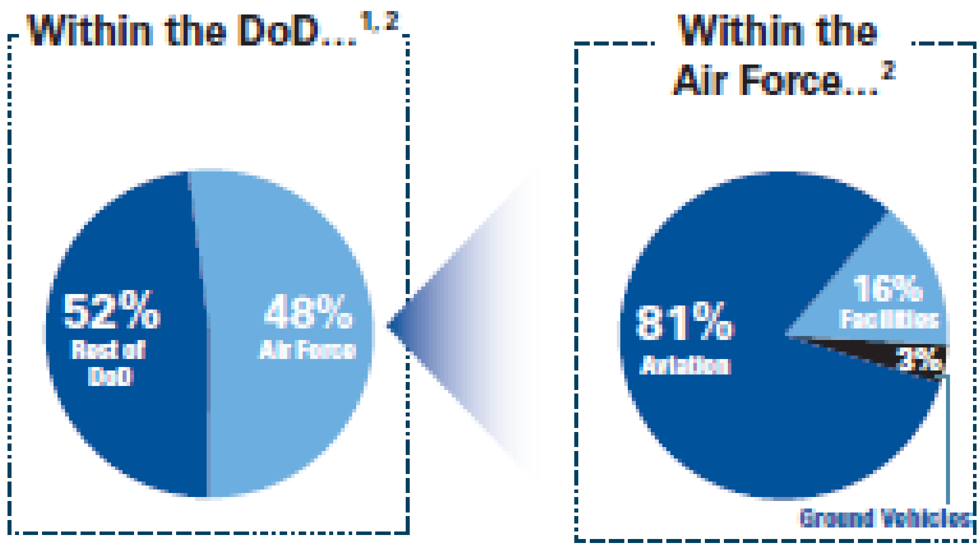


Figure 13. Air Force Energy Consumption within the Department of Defense. Source: U.S. Air Force (2013).

The 2013 U.S. Air Force Energy Strategic Plan affirms that the Air Force's Mobility Air Forces (MAF), under the Air Mobility Command (AMC), created the Aviation Fuel Efficiency Office (FEO) to lead implementation of improvements to aviation fuel conservation. The purpose of the FEO is to carry out the Air Force vision for fuel efficiency across its fleet. This strategic plan maintains that all MAF personnel are empowered to recommend or suggest ideas on ways that energy can be conserved. Consequently, these ideas are given to the proper personnel, and presented to the Air Force's corporate structure. According to this plan, the Air Force asserts that efforts to save fuel are focused on six major areas: science and technology, planning, policy, maintenance, execution, and fuel-efficient aircraft systems. A set of fuel-savings metrics as well as required reporting have also been established (U.S. Air Force, 2013).

In 2012, the U.S. Department of Energy published an article titled "Air Force Achieves Fuel Efficiency through Industry Best Practices," stating that the Air Force is collaborating with private industry and with other federal agencies to help determine where energy weaknesses exist, identify lessons learned, and put potential solutions in place to help improve the service's current position on

energy. Some of the best practices identified in this article include: data capture and analysis to highlight fuel reduction opportunities, removal of excess equipment and supplies to reduce weight, fuel load planning, flight planning to minimize fuel consumption, cost analysis to reduce total operating costs, and routine cleaning of engines resulting in reduced maintenance costs and fuel consumption. AMC has incorporated all of these methods into its operations. Additionally, the article states that the Air Force has included an online repository for fuel data collection and reporting called the Wing Dashboard, which all personnel within the MAF have access to. The Wing Dashboard contains a myriad of metrics to report fuel efficiency for the overall Air Force fleet (U.S. Department of Energy, 2012).

In 2015, the Air Force published a fact sheet for Energy Action Month. This fact sheet depicts other practical examples underway within the Air Force to reduce operational energy which include investing in new technologies such as the KC-135 and C-5M propulsion upgrade programs. These programs move cargo more efficiently, farther, and in less time, with lower fuel costs and maintenance costs. Another example listed in the fact sheet shows that the Air Force is applying commercial solutions for aviation such as introducing cost index flying into flight planning, fielding speed and altitude optimization, and investing in a four dimensional flight planning service for the future. Additionally, the Air Force is using a USTRANSCOM program called Agile Transportation for the 21st Century to assist logisticians, pilots, and loadmasters by reducing flight time and reducing fuel requirements. Figure 14 shows some of the additional examples that the Air Force is undertaking to reduce operational energy (U.S. Air Force, 2015).

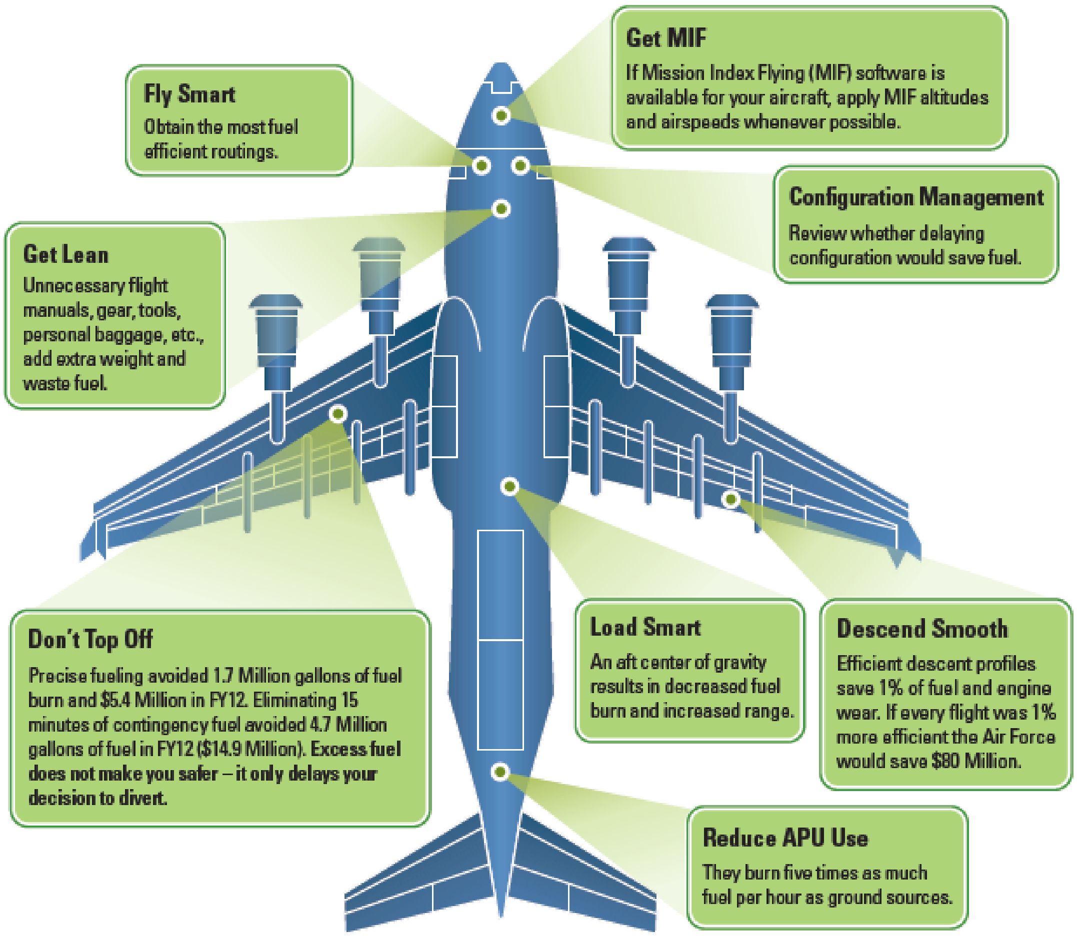


Figure 14. “Do Your Part,” Practical Examples of Air Force Energy Reduction Initiatives. Source: U.S. Air Force (2015).

According to the U.S. Air Force Energy Strategic Plan published in 2013, the Air Force is incorporating operational energy initiatives throughout its life cycle operations when compared to other services. In order to ensure that energy is considered in all things that the Air Force does, this service maintains governing bodies across the entire Air Force—at the headquarters level, at all the major commands, and at all the installations. The Air Force states that these cross-functional governing bodies “provide guidance and oversight, as well as evaluate the policies and programs, and resources needed to meet the Air Force energy goals and objectives” (U.S. Air Force, 2013). By doing this, the Air Force is improving its operational capabilities as well as maximizing fiscal resources.

This strategic plan goes on to state that as technology continues to develop and resource availability shifts, the Air Force approach to energy will continue to evolve. Figure 15 shows that the governing structure is divided into three levels and is headed by an Air Force Energy Council (U.S. Air Force, 2013).

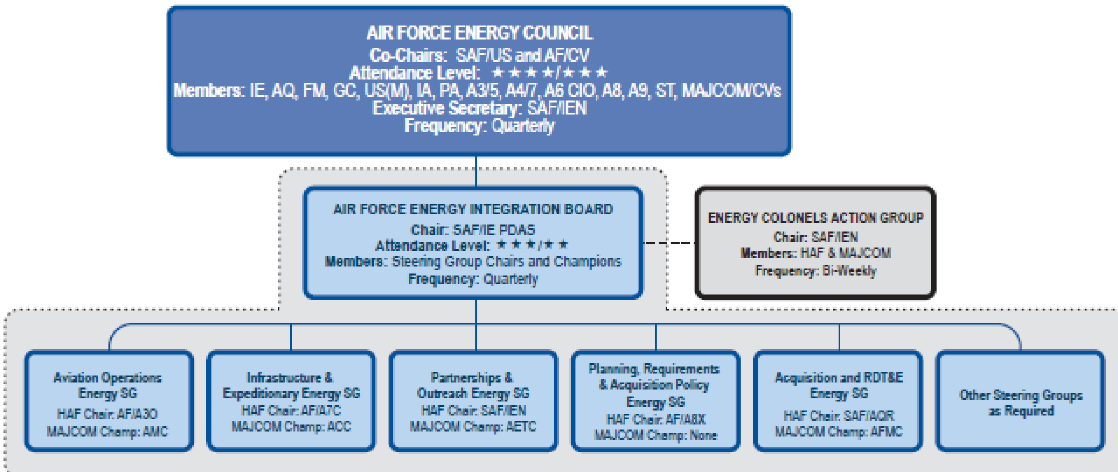


Figure 15. Air Force Energy Governance Structure. Source: U.S. Air Force Energy Strategic Plan (2013).

The 2013 U.S. Air Force Energy Strategic Plan states that the Energy Council is responsible for strategic oversight and guidance of addressing the energy challenges for the entire Air Force. The Council also identifies, integrates, and balances the investments needed to meet the energy goals and objectives. Additionally, the plan asserts that the Council is empowered to establish organizations and steering groups that focus on specific energy-related issues such as aviation operations, planning, energy security, expeditionary energy, infrastructure energy, research and development, test and evaluation, and outreach. The Air Force produced the Energy Strategic Plan which is the all-inclusive energy master plan for this service, required by 10 USC § 2911. In addition to this plan, the Air Force also develops an implementation plan on an annual basis that portrays specific tasks and activities for the approaching execution year, as well as reviews the recurring events that are required for this

service to attain its energy targets. The last portion of the Air Force's strategic plan is the yearly budget request which serves as the start point for funding the activities required to meet the energy goals (U.S. Air Force, 2013).

2. Navy and Marine Corps

The Department of the Navy's Energy Program for Security and Independence, published in April 2010, states that the Naval forces require energy to fuel all of its operations. Within the DOD, the Department of the Navy (DON) accounts for 34% of total energy consumption when compared to the other services—the Army and Air Force. Figure 16 shows the consumption across all domains—aviation, maritime, shore, and expeditionary domains (U.S. Department of the Navy, 2010).

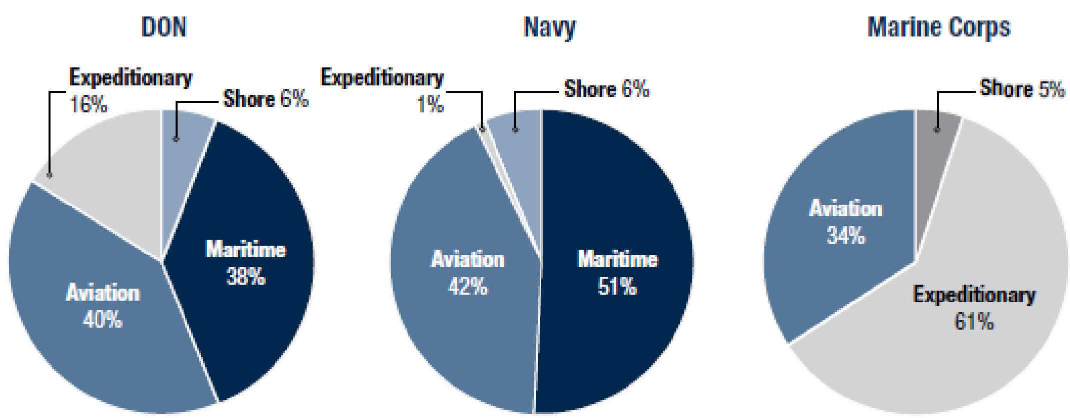


Figure 16. Energy Consumption across all DON Domains. Source: U.S. Department of the Navy (2010).

The DON's Energy Program for Security and Independence (2010) is made up of five elements intended to drive specific actions to meeting the goals set forth by the Secretary of the Navy. These elements are:

- Strategic Partnerships
- Energy Management
- Energy Efficient Acquisition

- Science and Technology
- Behavioral Change

The DON's energy program asserts that the Secretary of the Navy plans to take crucial steps such as requiring energy as a factor in the award of new contracts as well as contemplate the amount of energy contractors use as part of the overall acquisition process, which is currently not being done. For tactical systems, the DON's energy program states that the Marine Corps and Navy plan to incorporate the FBCF methodology in determining energy life-cycle costs and utilize the E-KPP to set the energy demand for new systems as well as optimize operational effectiveness. The DON has established a governing structure for energy management across the Naval enterprise and is shown in Figure 17. The DON affirms that this structure sets forth the roles for PPBE as well as a reporting structure for policy and function implementation within the DON (U.S. Department of the Navy, 2010).

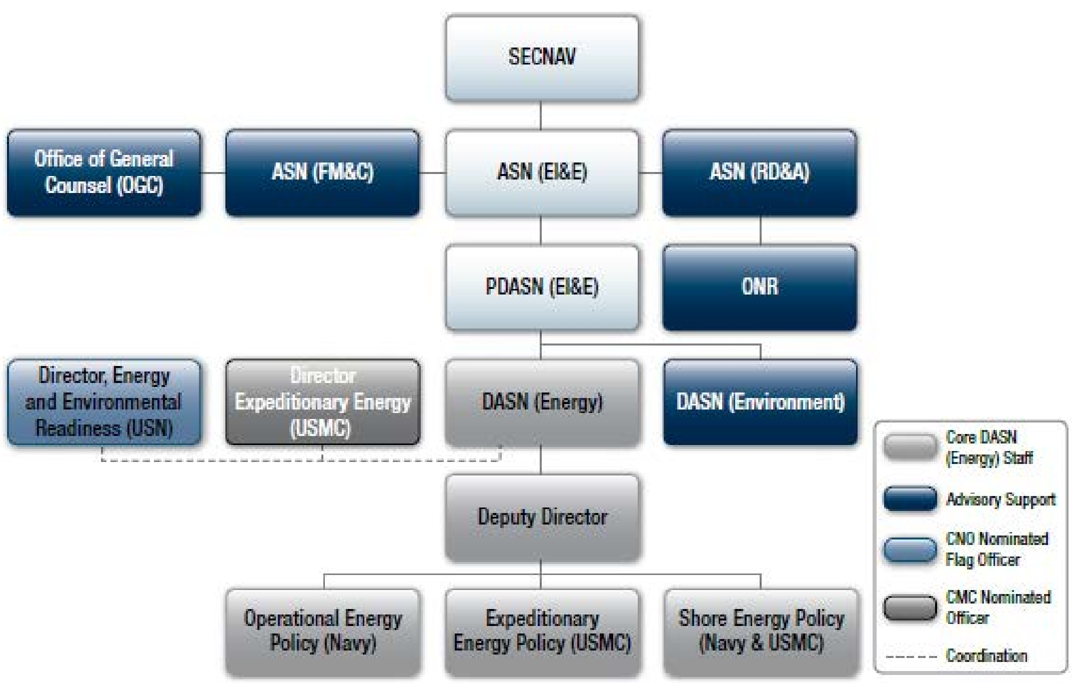


Figure 17. DON Energy Management Governance Structure. Source: U.S. Department of the Navy (2010).

According to the DON's Energy Program for Security and Independence (2010), the DON realizes that developing and utilizing advanced technologies is important to reach all of the energy goals set forth. The DON is partnering with other agencies, laboratories, and universities and working with industry to accelerate advanced technologies, mature and validate new technologies, and investigate other technologies that may disrupt the existing market. The program affirms that the DON is investing in maritime advancement of new engines with innovative technologies. The DON's Energy Program also states that the Hybrid Electric Drive (HED) technology will improve the way Naval ships operate, by allowing them to move at slower speeds without utilizing the ship's primary engines, resulting in the use of less energy. Additionally, the Incentivized Energy Conservation Program (i-ENCON) and Smart Voyage Planning software will permit the Naval personnel to utilize energy planning as a better approach to conserving energy. The DON is also developing improvements to its engines in aircraft in order to reduce the amount of fuel used. (U.S. Department of the Navy, 2010).

The article "Navy Energy Vision for the 21st Century," published in 2010, states that one of the primary energy efficiency initiatives for Naval aviation is the use of training simulators. This technology allows more training and readiness to be realized and provides superior training at reduced cost and risk. Additionally, Naval and Marine Corps Air Stations have achieved savings by using fuel trucks, during refueling of aircraft, instead of hot skids. Fuel savings have also been realized by certification of aircraft to operate at higher altitudes. According to the article, these higher altitudes are set aside for commercial airliners, which are more efficient. Naval aviation is evaluating current technological solutions such as improved turbine and compressor designs to improve energy performance and efficiency in currently fielded systems. Additionally, the article states that Naval aviation is also looking into drag-resistant aircraft coatings after demonstrating fuel savings in the commercial world. On the expeditionary side, the Navy is exploring fuel efficiency upgrades to mobility platforms such as the

Landing Craft Air Cushion which is expected to result in fuel savings up to 10%. Like other services and DOD, the Navy is looking to incorporate a FBCF to account for total cost of procuring and supplying fuel to various deployed platforms. Moreover, the article also states that the DON is also looking into different mechanisms to enforce energy efficiency considerations for the defense industry (U.S. Department of the Navy, 2010).

The DON's Energy Program for Security and Independence (2010) states that the DON's overarching goal is to develop projects that allow them to meet the energy goals set forth by the Secretary of the Navy and comply with all DOD policy directives, executive orders, and statutory mandates. The DON plans to pursue innovative financing mechanisms and funding arrangements to offset the high costs for emerging energy technologies. This Energy Program also states that the DON plans to partner with the Department of Energy, the U.S. Department of Agriculture, state energy offices, regional energy offices, other federal agencies, non-governmental organizations, and other utility service providers to exchange energy information, explore incentives, and leverage resources in order to construct and execute its energy program (U.S. Department of the Navy, 2010).

3. Army

In the briefing "The Army Energy and Sustainability Program," Mr. Richard Kidd (n.d.) states that the Army has "historically undervalued energy and energy security" and "unintentionally treated energy as a free good" (p. 5). Kidd, the deputy assistant secretary of the Army for Energy and Sustainability, goes on to assert that the Army acknowledges reducing fuel demand will expand capability, reduce logistical burdens, and save lives. In 2012, the G-4 Public Affairs published an article titled "Army Launches Smart Operational Energy Use Campaign, Identifies 10 Initiatives." This article states that the Army secretary, chief of staff, and sergeant major of the Army issued a "Call for Action," challenging the Army to transform its culture regarding operational energy. The

Operational Energy Office was officially established under the G-4 Deputy Chief of Staff of Logistics. Under this “Call for Action,” a list of initiatives were released to provide substantial energy savings for vehicles, aircraft, and soldiers. Some of these initiatives include:

- Apache Aviation Simulator – Located at Fort Rucker, Alabama, this simulator affords substantial fuel reduction (30% to 50%) because soldiers use the simulator instead of real aircraft for training. This simulator allows increased soldier training as well as reduced time and deterioration on aircraft. The reduction in flight hours also decreases the risk to equipment and pilots.
- Tactical Fuels Manager Defense (TFMD) – This automated tool accounts for fuel and provides assistance, that is mission critical, in decision making for air, ground, and marine fueling requirements at the enterprise, command, or base levels. TFMD is currently being utilized at various sites and provides significant insight to fuel consumption and availability of stock.
- Improved Turbine Engine Program – Discussed in Chapter IV of this project, this replacement engine will minimize fuel consumption for the Apache and Black Hawk fleet as well as improve lift, increase range, and reduce maintenance and production costs.
- Vehicle Modernization – Fuel efficiency for the Abrams and Bradley will be increased through Engineering Change Proposals. This includes integrating an auxiliary power unit under the vehicle’s armor to reduce fuel consumption while the Abrams vehicle is stationary. The powertrain for the Bradley will be upgraded to reduce vehicle weight and increase fuel efficiency.
- Performance of Future Platforms – The Army plans to leverage items such as design, material, and other enhancements to meet the demands of energy-informed operations for future platforms. (G-4 Public Affairs, 2012)

In the 2016 article titled, “What is the Army doing with Operational Energy?,” MAJ Ryan Hulse writes that the Army acknowledges capability developers at the Training and Doctrine Command need to add the energy KPP to CDDs and CPDs and follow the updated 2015 JCIDS manual, which provides instructions to develop the energy KPP. MAJ Hulse states that as the Army deploys to fight abroad on an increased basis, the Army will continue to evaluate

these energy saving capabilities at warfighting assessments and other Army-related evaluations. Additionally, MAJ Hulse says that the Army is also supporting the development autonomous aerial delivery and autonomous convoy operations to reduce risk to soldiers, minimize the logistics footprint, and allow faster turnaround time for deployed units (Hulse, 2016).

B. AS IT RELATES TO TRAINING

The 2016 DOD Operational Energy Strategy states that the Department recognizes training and education should be expanded to include energy efficiency as well as best practices in order to improve energy use in current operations. This OE strategy also asserts service initiatives such as modeling and simulation, war games, and focused analysis, supported by the Operational Energy Capability Improvement Fund (OECIF), will be utilized to assess and determine the effects of operational energy demand of future CONOPS. The DOD then plans to work with concept leads to apply necessary changes to facilities, materiel, organization, personnel, policy, and doctrine. The DOEB will be the lead for coordinating with effort with DOD components. This includes improving energy information fidelity and making it available to planners and commanders in order to account for the use of energy across all kinds of equipment. The 2016 OE strategy goes on to say that the DOD will continue improvements to dashboards, tools for decision-support, as well as planning and routing tools to enable members of the Services to utilize this information while in the field. Additionally, the DOD plans to include operational energy in various exercises and training and incorporate operational energy considerations into existing elective courses within the military education curriculum on logistics, strategy, acquisition, and campaign planning (DOD, 2016).

1. Air Force

The U.S. Air Force Energy Strategic Plan (2013) states the Air Force recognizes one of the primary ways to foster a culture of energy awareness is by education and training. This strategic plan asserts that the Air Education and

Training Command is performing a complete review of all the training related material, to make sure that operational energy concepts are included. The Air Force acknowledges in its strategic plan that this is one of the largest reviews ever done in its history. Additionally, this strategic plan says the Air Force released an on-line module that provided an overview of the service's approach to OE. The module includes tools for commanders to utilize to emphasize energy in respective missions as well as energy techniques, tactics, and procedures to be used at home and at work. The Air Force has also invested in an effort called Distributed Mission Operations. This effort links simulators for the different types of aircraft resulting in increased training event productivity (U.S. Air Force, 2013).

2. Navy and Marine Corps

The Navy Energy Training and Education (ET&E) Plan, published in July 2015, asserts that the Secretary of the Navy established a mandate to develop training and education for all uniformed personnel. This plan states that the ET&E Working Group was established in July 2013 to assess the extent and quality of energy and identify training gaps in its ET&E Continuum. The Navy's ET&E plan is a comprehensive strategy to include learning opportunities about energy into the enlisted and officer Training and Education Continuum that will be designed to inform personnel in a positive manner, change their behavior, and affect a cultural change throughout the Navy. The Navy ET&E Working Group identified five energy learning opportunity levels and target audiences to serve as the basic structure for developing a Continuum that is comprehensive and fleet-wide:

- General ET&E
- Subject Matter Expertise ET&E
- Leadership ET&E
- Advanced Specialized ET&E
- Fleet Evaluation

Additionally, the Navy is planning to augment the existing curriculum at other Naval institutions such as the Naval War College, Naval Postgraduate School, and the Naval Education and Training Command Schools. Starting in FY15, the Navy will focus on four ET&E areas for development, referred to as Block A:

- Apprentice School Training
- Officer Accession Training
- Commanding Officer/Executive Officer/Department Heads Training
- Senior Enlisted Training

Vehicles for ET&E will include formal classroom training, e-Learning modules, webinars, training documents, and training films. Delivery methods will be identified based on priorities and resources. The ET&E Working Group will evaluate the Continuum every six months in order to identify additional gaps or areas for further development (U.S. Department of the Navy, 2015).

The DON's Energy Program for Security and Independence (2010) states that the DON plans to implement initiatives for cultural change to ensure that all personnel understand that energy management is a priority in all shore, tactical, and expeditionary missions. Associating mission achievement to the importance of energy security and efficiency will result in a sense of energy excellence being instilled in all DON personnel. The DON will use Earth Day in April and Energy Awareness Month in October to encourage personnel to show commitment to energy program goals. This program also asserts that energy education programs and awards will help focus personnel on accomplishing and achieving the energy goals set forth by the Secretary of the Navy. The DON plans to connect energy efficient behaviors to the performance advancement and assessment process (U.S. Department of the Navy, 2010).

3. Army

In his 2016 article, MAJ Hulse writes that the Army Operational Energy Training Strategy provides the plan for OE practices, techniques, and concepts to be incorporated into the self-development, operational, and institutional training

domains. In this article, MAJ Hulse states that operational energy training is primarily divided into three efforts: education, technical training, and awareness. The operational domain will include OE training through technical and home station training for advisers, operators, and power managers. MAJ Hulse also asserts that operational energy issues will be incorporated into contingency training scenarios at combat training centers, as practicable. On the institutional side, OE awareness training will begin during initial military training. MAJ Hulse writes that the intent is to establish OE principles as habits at the start of military service and continue through all levels of military development. The technical portions of OE are currently being taught in courses that are military occupational specialty (MOS) specific, Hulse writes that more energy-related initiatives should be added to other courses. The self-development portion of this training will include efforts such as online learning, job aids, training handouts, and graphic training aids (Hulse, 2016).

The Army has a plan to include OE concepts into logistics publications; however, no OE doctrine exists for expeditionary operations nor is it addressed in any operational publications. The Army plans to work with proponents to add OE considerations into select operational publications, such as the following:

- *Army Doctrine Reference Publication (ADRP) 1, The Army Profession*
- ADRP 4-0, *Sustainment*
- ADRP 5-0, *The Operations Process*
- ADRP 6-0, *Mission Command*
- ADRP 7-0, *Training Units and Developing Leaders*
- Field Manual 4-95, *Logistics Operations*
- Field Manual 6-0, *Commander and Staff Organization and Operations*
- *Allied Logistic Publication 4.2, Land Forces Logistics Doctrine* (Hulse, MAJ R., 2016)

The Army has incorporated energy into coursework at the U.S. Military Academy at West Point and integrated OE topics into course modules at the Command and General Staff College. The topic “Energy and National Security” has been added to the Key Strategic Issues List at the U.S. Army War College. Additionally, OE is used as a topic for a required paper in the Theater Logistics Course at Army Logistics University. Additionally, “The Power Is In Your Hands” trifold was published and signed by the Sergeant Major of the Army, Chief of Staff of the Army, and the Secretary of the Army to evoke a culture change regarding energy throughout the Army (*U.S. Army Stand-To*, 2013).

VI. CONCLUSION AND RECOMMENDATIONS

As of late 2016, a gallon of gas costs the average American around two dollars a gallon. However, one should consider the risk to loss of life and how much that same gallon costs when it must be delivered to the battle field in Afghanistan, or as highlighted in the recent National Security Strategy, transported across the Pacific Ocean. This research paper has again highlighted that DOD is the nation's single largest user of petroleum fuel and attempted to determine what DOD is doing to reduce its consumption. The authors of this research paper have discussed the relevance or need for a comprehensive strategy, reviewed those major strategies which started essentially in 2001, analyzed the related DOD acquisition documents, processes and instructions, and lastly, reviewed the DOD services' progress to promulgate new policies, processes and some of the weapon system designs that consume less fuel.

Projecting sea, air, and land power worldwide requires access to the energy necessary to sustain DOD's weapons systems and mobility platforms. The availability of energy for military operations must serve as a strength for U.S. forces, and not as a weakness. DOD's energy resources must be secure, of sufficient quantity, and available when needed for whatever duration is necessary to support the full spectrum of military operations. This makes energy the critical enabler that underpins our military's fundamental contribution to U.S. national security.

This research paper has captured and highlighted the extensive effort underway by the DOD to understand how to more accurately measure cost of fuel with FBCF, and what is being done within the DOD to improve the energy performance of fuel consuming platforms and weapon systems. It is apparent that the DOD is just starting to understand and consider the threats related to fuel reliance. We believe this shift in thinking can be linked to a few major factors, such as the 9/11 attacks, increased unit cost of gas to four dollars a gallon, enemy tactics in the USCENTCOM region to cut off energy supply lines,

Congressional directives, and the recent National Security Strategy highlighting the focus shift to the USPACOM region which requires extended supply lines that are magnified by anti-access and area denial threats.

This research project essentially started because a small team of DOD acquisition professionals understood that the primary way to reduce reliance on fuel is to design, modify, produce, and field more fuel-efficient weapon systems, and then optimize their application and usage through best practices such as those seen in the commercial sector (ground and air). Yet before 2001, it appeared as if DOD considered only warfighting performance parameters in design and modification programs, and not including reliance on energy or fuel.

Accordingly, it is essential that operational energy considerations be addressed in DOD's policies and a top priority placed on DOD's efforts to improve and deliver higher fuel efficiency weapon systems to our soldiers, sailors, airmen, and Marines. Trends of the past to ignore fuel consumption in weapon system designs are now just starting to shift due to our nation's financial, operational and strategic pressures. The Duncan Hunter National Defense Authorization Act for FY 2009, 10 USC 2911 § 332, played a key role in driving real change within the DOD to consider fuel demands, burden on the supply chain, and cost analyses such as FBCE and FBCF in requirements and associated acquisitions.

It is critically important that the DOD remain focused on improving total ownership cost calculations and modeling, to include FBCF, and that the Joint Staff and service chiefs drive their respective requirements communities to utilize the Energy Key Performance Parameter in future weapon systems development efforts. Without requiring measureable improvements in energy consumption, the services and their acquisition communities will continue to myopically focus on warfighting enhancements while ignoring the logistical burden laid at the feet of DLA and the deployed commanders to keep energy supply lines open. The DOD trend continues to focus more on existing weapon system modernization efforts rather than costly and lengthy weapon system new-starts, such as upgrading the

B-52, or the Apache AH-64D to AH-64E. Now that this is the trend, Congress and DOD need to modify the PPBE process to require the services to reduce fuel/ energy consumption of these legacy fielded systems as they modify and update warfighting capabilities. Before a specific weapon system modification funding line is approved, the requesting service should be required to include plans to incrementally reduce reliance of fuel/energy on that fielded system. Projects like the Army's ITEP or the USAF's Cost Index Flying are practical examples underway to reduce operational energy to include investing in new technologies such as the KC-135 and C-5M propulsion upgrade programs that move cargo more efficiently, farther, and in less time, with lower fuel costs and maintenance costs.

It is apparent that the services are now making good headway. The DOD should leverage best practices from each service and also the commercial sector to continue this difficult and complex shift in thinking. Anticipated future national challenges and threats noted in the NSS should be driving DOD to have a greater sense of urgency and vigilance.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX. ADDITIONAL INFORMATION

The law that appears to have driven real change in the JCIDS:

1. NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2009 10 USC 2911 § 332.

CONSIDERATION OF FUEL LOGISTICS SUPPORT REQUIREMENTS IN PLANNING, REQUIREMENTS DEVELOPMENT, AND ACQUISITION PROCESSES.
(b) CAPABILITY REQUIREMENTS PROCESS.—The Secretary of Defense shall develop and implement a methodology to enable the implementation of a fuel efficiency key performance parameter in the requirements development process for the modification of existing or development of new fuel consuming systems.
(c) ACQUISITION PROCESS.—The Secretary of Defense shall require that the life-cycle cost analysis for new capabilities include the fully burdened cost of fuel during analysis of alternatives and evaluation of alternatives and acquisition program design trades.
(g) FULLY BURDENED COST OF FUEL DEFINED.—In this section, the term ‘‘fully burdened cost of fuel’’ means the commodity price for fuel plus the total cost of all personnel and assets required to move and, when necessary, protect the fuel from the point at which the fuel is received from the commercial supplier to the point of use.

2. LAW DEFINING OPERATIONAL ENERGY AND RELATED TERMS:

US Law Title 10 U.S.C. § 2924

(3)

(A) The term “energy security” means having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet mission essential requirements.
(B) In selecting facility energy projects that will use renewable energy sources, pursuit of energy security means the installation will give favorable consideration to projects that provide power directly to a military facility or into the installation electrical distribution network. In such cases, projects should be prioritized to provide power for assets critical to mission essential requirements on the installation in the event of a disruption in the commercial grid.

(4) The term “hybrid,” with respect to a motor vehicle, means a motor vehicle that draws propulsion energy from onboard sources of stored energy that are both—

(A) An internal combustion or heat engine using combustible fuel; and

(B) A rechargeable energy storage system.

(5) The term “operational energy” means the energy required for training, moving, and sustaining military forces and weapons platforms for military operations. The term includes energy used by tactical power systems and generators and weapons platforms.

(6) The term “petroleum” means natural or synthetic crude, blends of natural or synthetic crude, and products refined or derived from natural or synthetic crude or from such blends.

LIST OF REFERENCES

About the Department of Defense (DOD). (n.d.). Retrieved from http://www.defense.gov/About-DOD

About the United States Pacific Command (USPACOM). (n.d.). Retrieved from http://www.pacom.mil/About-USPACOM/

AcqNotes. (2016). *PPBE Process Map, A simple source of DOD Acquisition Knowledge for the Aerospace Industry.* Retrieved from http://www.acqnotes.com/acqnote/acquisitions/ppbe-map

Army Material Systems Analysis Activity (AMSAA), (2014). *Improved turbine energy (ITE) analysis of alternatives* (Technical Report No. TR-2014-30). Aberdeen Proving Ground, MD: Author.

Assistant Secretary of Defense for Operational Energy Plans and Programs (ASD(OEPP)). (2011). *Energy for the warfighter: Operational energy strategy*. Retrieved from http://www.secnav.navy.mil/eie/ASN%20EIE%20Policy/DODOperationalEnergyStrategy.pdf

Belasco, Amy. (2009). *Troop levels in the Afghan and Iraq wars, FY2001-FY2012: Cost and other potential issues* (CRS R40682). Washington, DC: Congressional Research Service. Retrieved from http://fas.org/sgp/crs/natsec/R40682.pdf

Bochman, Andy. (2008). *DOD energy blog.* Retrieved from http://dodenergy.blogspot.com/2008/09/friedman-new-book-marines-solar-in-iraq.html

Chairman of the Joint Chiefs of Staff (CJCS). (2007). *Joint capabilities integration and development system process* (CJCS Manual 3170.01). Washington, DC: Author.

Chairman of the Joint Chiefs of Staff. (2009, February). *Joint capabilities integration and development system process* (CJCS Manual 3170.01). Washington, DC: Author.

Chairman of the Joint Chiefs of Staff. (2010). *Joint capabilities integration and development system process* (CJCS Manual 3170.01). Enclosure (B) (2) Energy Efficiency KPP. Washington, DC: Author.

Chairman of the Joint Chiefs of Staff. (2012). *Joint capabilities integration and development system process.* Enclosure (B) Appendix (A) p. BA-3 (6) Energy. (CJCS Manual 3170.01). Washington, DC: Author.

Chairman of the Joint Chiefs of Staff. (2015). *Joint capabilities integration and development system process* (CJCS Manual 3170.01). Includes errata as of 18 December 2015. Enclosure (D) Appendix (A) Para e. p. D-A 3-4: Energy KPP. Washington, DC: Author.

Defense Acquisition University (DAU). (2016). *Defense Acquisition Portal*. Retrieved from https://dap.dau.mil/aphome/pages/default.aspx

Defense Science Board. (2001). *More capable warfighting through reduced fuel burden*. Report of the Defense Science Board (DSB) Task Force on Improving Fuel Efficiency of Weapon Platforms. Washington, DC: U.S. Government Printing Office.

Defense Science Board. (2008). *More fight—Less fuel*. Washington, DC: U.S. Government Printing Office.

Department of Defense (DOD). (2010). *Quadrennial defense review report*. Washington, DC: U.S. Government Printing Office.

Department of Defense. (2012). *Operational energy strategy: Implementation plan*. Retrieved from Office of the Under Secretary of Defense for Acquisition, Technology and Logistics website: http://www.acq.osd.mil/eie/Downloads/OE/20120306_OE_Strategy_Implementation_Plan.pdf

Department of Defense. (2013). Chapter 3, Affordability and life cycle resource estimates. In *Defense acquisition guidebook.* Retrieved from Retrieved from Acquisition Community Connection website: https://acc.dau.mil/docs/dag_pdf/dag_ch3.pdf

Department of Defense. (2014). *Quadrennial defense review 2014*. Retrieved from http://archive.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf

Department of Defense. (2016)*. 2016 Operational energy strategy*. Retrieved from http://www.acq.osd.mil/eie/Downloads/OE/2016%20DoD%20Operational%20Energy%20Strategy%20WEBc.pdf

Dubbs, S.R. (2011). *Estimating the fully burdened cost of fuel using an input-output model—A micro-level analysis*. Retrieved from Calhoun, The NPS Institutional Archive: http://calhoun.nps.edu/bitstream/handle/10945/5605/11Sep_Dubbs.pdf?sequence=1&isAllowed=y

Duncan Hunter National Defense Authorization Act for Fiscal Year 2009, Pub. L. No. 110-417. 122 Stat. 4356 (2008). Retrieved from U.S. Department of Defense: http://www.dod.gov/dodgc/olc/docs/2009NDAA_PL110-417.pdf

Energy Security and Research: Testimony before the Senate Subcommittee of the Committee on Appropriations, 113th Cong. (2014) (testimony of Edward Thomas Morehouse, Jr.).

G-4 Public Affairs. (2012). *Army launches smart operational energy use campaign, identifies 10 initiatives*. Retrieved from U.S. Army website: https://www.army.mil/article/89693/

General Accounting Office (GAO). (2008). *Defense management: Overarching organizational framework could improve DOD's management of energy reduction efforts for military operations* (GAO-08-523T). Washington, DC: Author.

General Accounting Office. (2012). *Defense management: Guidance and progress measures are needed to realize benefits from changes in DOD's joint requirements process* (GAO-12-339). Washington, DC: Author.

General Accounting Office. (2015). *Defense energy: Observations on DOD's investments in alternative fuels* (GAO-15-674). Washington, DC: Author.

Hulse, MAJ R. (2016). *What is the Army doing with operational energy?* Retrieved from U.S. Army website: https://www.army.mil/article/162412/What_is_the_Army_doing_with_operational_energy_

The JASON Group. (2006). *Reducing DOD fossil-fuel dependence* (JSR-06-135). McLean, VA: Author.

Kidd, R. (n.d.). *Army energy and sustainability program* [PowerPoint slides]. Retrieved from Assistant Secretary of the Army (Installations, Energy and Environment) website: http://www.asaie.army.mil/Public/ES/doc/2-General%20Presentation.pdf

Office of the Assistant Secretary of Defense for Energy, Installations and Environment (OASD(EI&E)). (2015). *DOD annual energy management report fiscal year 2014*. Retrieved from http://www.acq.osd.mil/eie/Downloads/Reports/Tab%20B%20-%20FY%202014%20AEMR_FINAL.pdf

Office of the Deputy Secretary of Defense. (2014, April 16). *Department of defense energy policy directive* (DODD 4180.01). Retrieved from DTIC website: http://www.dtic.mil/whs/directives/corres/pdf/418001_2014.pdf

Office of the Secretary of Defense (OSD). (2013, January 25). *Planning Programming Budgeting and Execution (PPBE) System Directive* (DODD 7045.14). Retrieved from DTIC website: http://www.dtic.mil/whs/directives/corres/pdf/704514p.pdf

Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD[AT&L]). (2015). *Fiscal year 2014 operational energy annual report*. Retrieved from Retrieved from Office of the Under Secretary of Defense for Acquisition, Technology and Logistics website: http://www.acq.osd.mil/eie/Downloads/OE/ FY14%20OE%20Annual%20Report.pdf

Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. (2015, January 07). *Operation of the defense acquisition system* (DOD Instruction 5000.02). Retrieved from Navy Small Business Intelligence Transfer website: http://www.navysbir.com /docs/500002p.pdf

Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. (2013, November 25). *Operation of the defense acquisition system* (DOD Instruction 5000.02). Retrieved from www.acq.osd.mil/osbp/sbir/docs/500002_interim.pdf

Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. (2008, December 08). *Operation of the defense acquisition system* (DOD Instruction 5000.02). Washington, DC: Author.

Program Executive Officer, Aviation. (2015). *Improved turbine engine (ITE) acquisition strategy.* Redstone Arsenal, AL: Author

Program Executive Officer, Aviation. (2016). *Improved turbine engine program (ITEP), army systems acquisition review council (ASARC) brief May 24, 2016.* Redstone Arsenal, AL: Author

Promulgate. (n.d.) Retrieved from http://www.merriam-webster.com/dictionary/ promulgate

Thompson, M. (2011). A question for the Obama administration. *Time.* Retrieved from http://nation.time.com/2011/04/24/a-question-for-the-obama-administration/

Title 10 U.S. Code Section 2911. (2015). Retrieved from GPO: https://www.gpo.gov/fdsys/pkg/USCODE-2010-title10/pdf/USCODE-2010-title10-subtitleA-partIV-chap173-subchapI-sec2911.pdf

Title 10 U.S. Code Section 2924. (2015). Retrieved from GPO: https://www.gpo.gov/fdsys/pkg/USCODE-2015-title10/pdf/USCODE-2015-title10-subtitleA-partIV-chap173-subchapIII.pdf

Under Secretary of Defense (Acquisition, Technology, and Logistics). (2007). *Fully burdened cost of fuel pilot program*. Washington, DC: U.S. Government Printing Office. Retrieved from http://www.acq.osd.mil/se/docs/USD-ATLMemo-Fully-Burdened-Cost-Fuel-Pilot-Program-10Apr07.pdf

U.S. Air Force. (2013). *U.S. Air Force energy strategic plan*. Retrieved from http://www.safie.hq.af.mil/shared/media/document/AFD-130325-132.pdf

U.S. Air Force. (2015). *Energy action month* [Fact Sheet]. Retrieved from http://www.safie.hq.af.mil/shared/media/document/AFD-141002-036.pdf

U.S. Army Stand-To. (2013). *Operational energy education efforts*. Retrieved from U.S. Army website: https://www.army.mil/standto/archive_2013-10-28

U.S. Department of Energy. (2012). *Air Force achieves fuel efficiency through industry best practices*. DOE/GO-102012-3725. Retrieved from https://www1.eere.energy.gov/femp/pdfs/af_fuelefficiency.pdf

U.S. Department of the Navy. (2010). *A Navy energy vision for the 21st century*. http://greenfleet.dodlive.mil/files/2010/10/Navy-Energy-Vision-Oct-2010.pdf

U.S. Department of the Navy. (2015). *Navy energy training and education plan*. Retrieved from Naval Aviation Energy Conservation Program website: http://airencon.dodlive.mil/files/2014/03/20150702-Navy-Energy-TE-Plan-FINAL-VERSION.pdf

U.S. Environmental and Energy Study Institute (EESI). (2011). *DOD's energy efficiency and renewable energy initiatives*. Retrieved from http://www.eesi.org/files/dod_eere_factsheet_072711.pdf

Wagner, J. and Singer, P. (2008). *Fueling the "balance": A defense energy strategy primer*. Retrieved from Brookings website: https://www.brookings.edu/wp-content/uploads/2016/06/08_defense_strategy_singer.pdf

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California